PB-216 358

A REPORT OF SPHAEROTILUS GROWTHS IN THE LOWER COLUMBIA RIVER. 1955, 1956 AND 1957

Public Health Service
Washington, D. C.

15 October 1958

DISTRIBUTED BY:

NTIS

National Technical Information Service
U. S. DEPARTMENT OF COMMERCE
5285 Port Royal Road, Springfield Va. 22151

Only copy

PB 216 358

LIBRARY
Environmental Protection Agency
5555 Ridge Ave., Cincinnati, O. 45213

A REPORT OF

SPHAEROTILUS GROWTHS

IN THE

LOWER COLUMBIA RIVER

1955, 1956 and 1957

A Cooperative Study of the

U. S. Public Health Service
Oregon State Sanitary Authority
Washington Pollution Control Commission

October 15, 1958

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S Department of Commerce
Springfield VA 22151

A REPORT OF

SPHAEROTILUS GROWTHS

IN THE

LOWER COLUMBIA RIVER

1955, 1956 and 1957

A Cooperative Study of the

U. S. Public Health Service
Oregon State Sanitary Authority
Washington Pollution Control Commission

October 15, 1958

INVESTIGATORS

H. C. Clare, Sanitary Engineer Director (R), Public Health Service, Water Supply and Water Pollution Control, Pacific Northwest, 211 U. S. Court House, Portland, Oregon - Project Coordinator.

A. E. Becker, Assistant Sanitary Engineer (R), Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio - Project Leader.

D. R. Peterson, Research Supervisor, Washington Pollution Control Commission, Olympia, Washington.

R. A. Wagner, Senior Biologist, Washington Pollution Control Commission, Olympia, Washington.

J. Behlke, District Engineer, Washington Pollution Control Commission, Olympia, Washington.

D. Benson, Assistant Sanitary Engineer, Oregon State Sanitary Authority, Portland, Oregon.

J. N. Wilson, Biologist, Public Health Service, Water Supply and Water Pollution Control, Pacific Northwest, 211 U. S. Court House, Portland, Oregon - Project Leader, Interim Studies and Lower Willamette River Section.

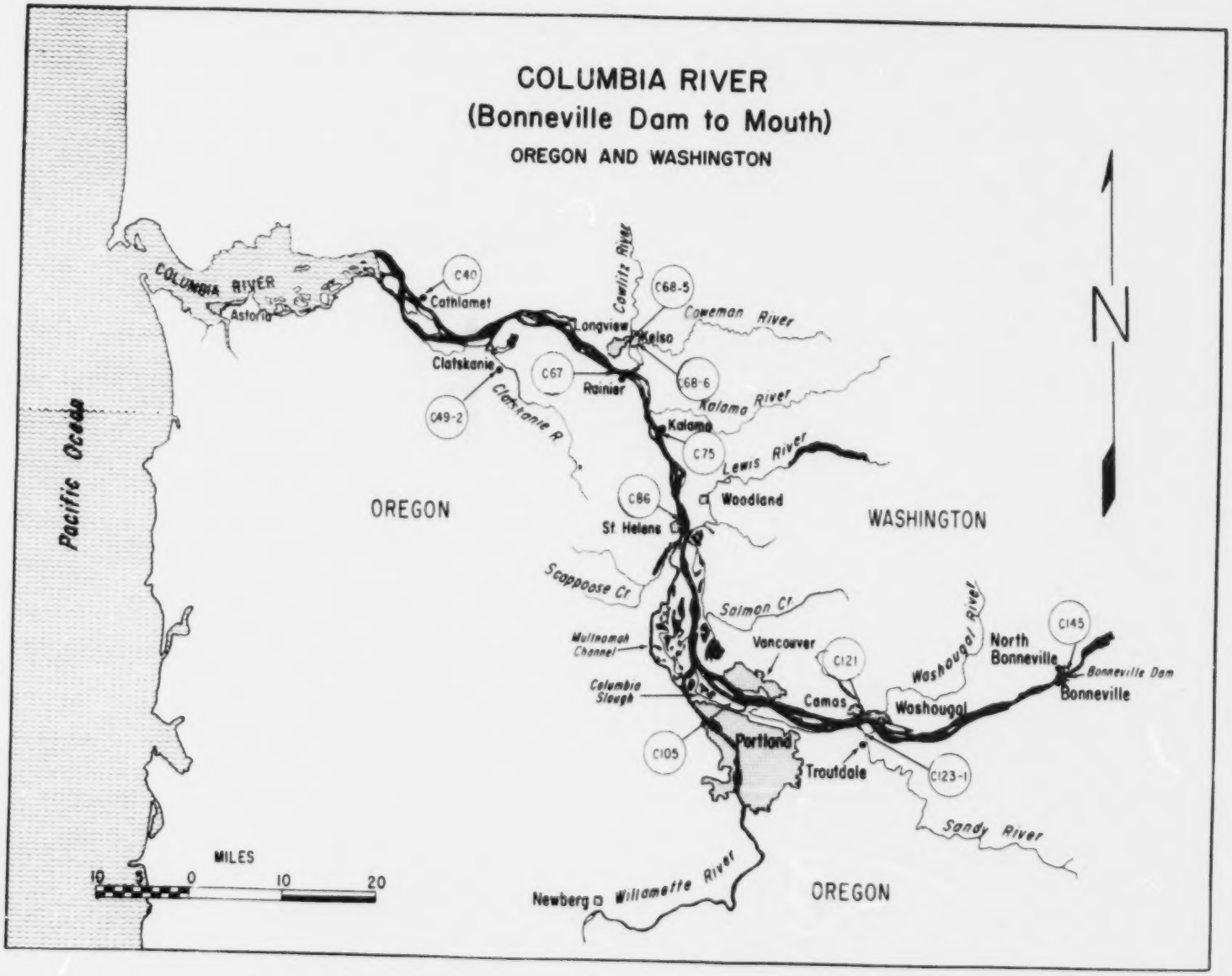
C. N. Shadix, Chemist, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

M. Currey, Chauffeur - Mechanic Field Sampler, Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

G. L. Toombs, Chemist, Oregon State Sanitary Authority, Portland, Oregon.

TABLE OF CONTENTS

	Page
Summary and Conclusions	1
Introduction	2
September-October, 1955 Study	5
Interim Period between Fall and Spring Studies	9
March and April, 1956 Study	10
Studies on Lower Willamette River	14
Reports of Commercial Fishermen's Comments	18
Discussion	21
Bibliography	24
Appendix I - Maps	
Appendix II - Description of Sampling Points	
Appendix III - Field Equipment and Methods	
Appendix IV - Laboratory Methods	
Appendix V - Tables	


COLUMBIA RIVER
(Bonneville Dam to Mouth)
OREGON AND WASHINGTON
Pacific Ocean
COLUMBIA RIVER
Astoria
C40
Cathlamet
Clatskanie
C49-2
Clatskanie R
C67
Rainier
Cowlitz River
Longview
Kelso
C68-5
Coweman River
C68-6
Kalama River
Kalama
C75
Lewis River
Woodland
C86
St Helens
OREGON
WASHINGTON
Scappoose Cr
Salmon Cr
Multnomah Channel
Vancouver
C121
Columbia Slough
Camas
Washougal River
Washougal
North Bonneville
C145
Bonneville Dam
Bonneville
C105
Portland
Troutdale
C123-1
Sandy River
MILES
10 5 0 10 20
Newberg
Willamette River
OREGON
N

SPHAEROTILUS GROWTHS IN THE LOWER COLUMBIA RIVER

A Joint Study of the U. S. Public Health Service, the Oregon State Sanitary Authority and the Washington Pollution Control Commission.

1955, 1956 and 1957

Summary and Conclusions

The field studies have shown that growth of Sphaerotilus is "triggered" into nuisance concentrations during certain seasons of the year between Camas and Longview in the Columbia and between Oregon City and Upper Portland Harbor in the Lower Willamette. Floods and freshets influence the growth. At such times growths are loosened en masse and transported many miles to points downstream. Moreover, high water and floods shorten time of flow to downstream points so that transportation of nutrients occurs over much longer distances and the range of active slime growth is extended accordingly. As a result, active growing areas extend periodically from Oregon City to the Columbia and from Camas to Puget Island below Cathlamet and adverse effects from attached slimes have been noted as far downstream as Astoria, Oregon, nine miles above the Mouth of the Columbia River. The major growth in the Columbia occurs largely on the Washington side. Sphaerotilus does not occur in significant amounts in the river above Camas.

The sulfite pulp mills are a major contributor to the production of Sphaerotilus and associated slimes in the Columbia River. Kraft mills, canneries and domestic sewage are other lesser contributors. Mill wastes are deficient in certain substances required for active Sphaerotilus growth, such as phosphates and nitrates; however, these other elements are present in the river as it reaches Camas.

The ponding of pulp mill wastes is practiced by most of the mills along the Willamette River at and above Oregon City during periods of low flow in the summer as a means of helping to maintain suitable (5 ppm or above) oxygen levels in the Willamette River. The release of these impounded wastes during high flow periods of the winter months comes at a time when water temperatures are usually in the optimum range for the growth of Sphaerotilus. These factors tend to aggravate the slime problem in the entire Lower Willamette River as shown by the results of chemical and physical tests and by increased increments of the slime growth on the tile boxes throughout the Lower Willamette to its junction with the Columbia River. The transport of dislodged slimes from growing areas in the Willamette into the Columbia River has been demonstrated

at times of freshet in the Willamette. Since freshets in the two rivers seldom coincide, these slimes add to the problem in the Columbia.

Introduction

In 1940-42 Lincoln and Foster conducted studies of the Lower Columbia River for Washington and Oregon pollution control agencies (1). These studies included an investigation of a slime material identified to consist largely of a "strain or strains of Sphaerotilus."

From this date until the period of the studies herein reported numerous investigations were made by both the Washington Pollution Control Commission and the Oregon State Sanitary Authority. Some of these investigations have been reported with other material in bulletins of the Washington Commission (2).

This slimy material grows in abundance in the river and at times interferes with the operations of a considerable fishing industry by clogging and allegedly deteriorating the nets of fishermen. Fishermen report that they are often able to make but one drift in the river before removing the nets, allowing them to dry, and shaking out the material. The nets are often so heavy with slime that the fishermen have difficulty lifting them into the boats. This condition has caused repeated complaints of the loss of income and has been the source of considerable concern to the fishing industry on the river.

Lincoln and Foster determined that the growth of the Sphaerotilus was associated with the presence of sulfite waste liquor (SWL) discharged from pulp mills on the river. Their studies indicated that the growth could be controlled by keeping the concentration of SWL below 50 ppm based on digester liquor containing 10 percent solids.

In order to accomplish this requirement, the mills on the Lower Columbia River constructed diffuser lines to mix the waste rapidly and intimately with the large flow of the river. This action by the mills resulted in lowering concentrations below 50 ppm in most instances, but the growth has persisted.

In 1955 the U. S. Public Health Service at the request of the Washington Pollution Control Commission and the Oregon State Sanitary Authority sent a team of investigators to the area from the Cincinnati Sanitary Engineering Center. This team joined with the members of the staffs of the two state agencies in a study of the Sphaerotilus problem. Some time later in the same year Crown Zellerbach Corporation embarked on a study of the river below Camas. These studies were accompanied by laboratory investigations conducted at Oregon State College by the

National Council for Stream Improvement.

The data herein presented are those obtained jointly by the Public Health Service and the state agencies. The study was made during two periods. The first is reported under date of November 21, 1955 and covers the studies made during September and October of that year. The second study was conducted during the following spring - March and April, 1956.

In the interim between the two periods and on occasions since the last period, the Portland office of the Public Health Service and the staff of the Oregon State Sanitary Authority have conducted studies both in the Columbia and the Lower Willamette Rivers.

The data collected from each of these studies have been compiled and are presented below. A map showing the Lower Columbia River, the location of pulp mills and major cities, and the drift areas used by fishermen is attached as Appendix I of this report.

Sphaerotilus

Sphaerotilus natans occurs in two forms. The first is a non-mucilaginous single cell bacterium which under certain nutrient conditions may develop into a sheathed filamentous form. Sugars (mono- and disaccharides), organic acids, alcohols and amino acids are utilized by the organism as a source of carbon. Nitrates and amino acids are used as a nitrogen supply.

Sphaerotilus prefers a pH above 6.0 and can withstand conditions up to pH 8.0. Although the optimum temperature for growth in rivers is from 5 to 15° C, it occurs more profusely in the colder months probably due to a lesser competition for the nutrients during those periods. Oxygen is required.

The amount of growth appears to vary directly with the concentration of available food and where this is the only limiting factor the greatest growth is in areas of low flow. High flows distribute the growth over longer stretchs of the stream. Numerous other forms of micro-organisms are associated with the sticky filamentous growths and add to the bulk and weight of the slime. On the basis of his sampling procedures, Liebmann (3) calculated that from a daily production of 100 tons of pulp by the sulphite process, a daily production of 70 tons of growth could be anticipated.

Velocity of flow is an important factor when correlated with available food supply for Sphaerotilus and related slime organisms. Where

nutrient content is held constant, increase in current velocity over a growing area enhances growth by increasing the total amount of food passing a given point per unit time. Furthermore, moderate current velocity favors growth in heavily silted areas by flushing silt and debris from the growth. However, excessive current velocities may be detrimental through scouring and abrasion by silt as indicated on page .

Phosphate concentration may be a limiting or stimulating factor in the growth of the organism, as indicated by results of research in progress at the Crown Zellerbach Research Department, Camas, Washington.(4)

Sphaerotilus grows in sections of streams which are not polluted as determined by the usual criteria for measuring pollution, as well as those in streams which are considered to be polluted. However, it requires the presence of nutrient material which results from the discharge of sewage and certain industrial wastes. This material is present in the Columbia River in amounts which support a heavy growth of Sphaerotilus but which does not have significant effect on the oxygen concentration.

Scope and Objectives

The general objectives of the survey were:

1. To locate the areas of active Sphaerotilus growth.

2. To develop methods to correlate the areas of growth with various concentrations of nutrients and certain physical factors.

3. To determine the effect of Sphaerotilus production in the Lower Willamette River upon the Columbia River.

SEPTEMBER - OCTOBER

1955 STUDY

Purpose

The purpose of the first survey was largely to develop techniques for both field and laboratory operations. This report outlines the progress made and summarizes the data collected. It does not present a complete tabulation or analysis of these data.

Sampling Stations

Sampling stations are shown on the series of maps of the Columbia River, Appendix I. These are described in the tabulation of sampling stations, Appendix II. The maps and tabulations show all stations used during the entire study.

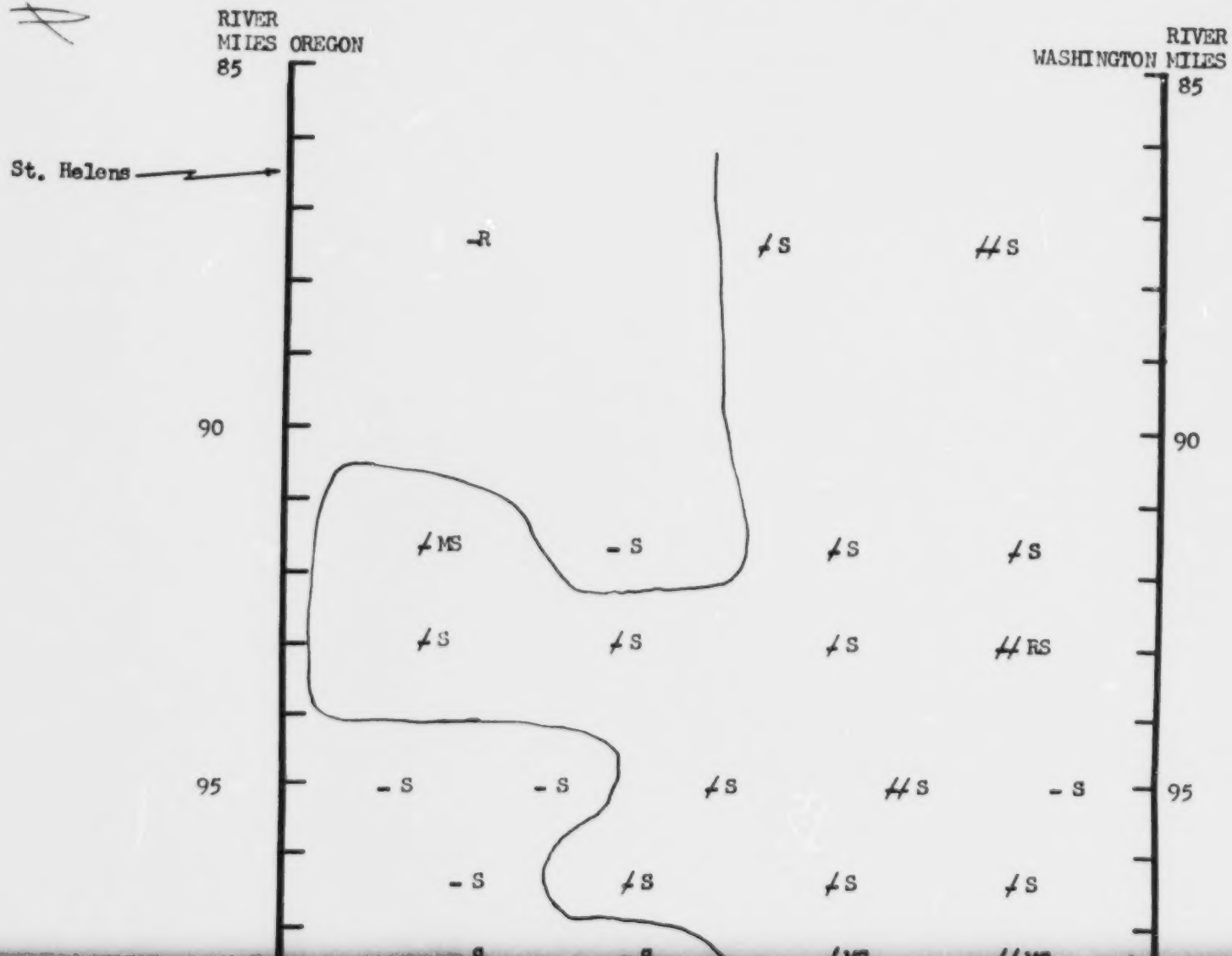
The area covered by this first survey was largely limited to a stretch of river approximately 35 miles in length from mile 120 to mile 85. This stretch included that part of the river considered to be critical in the Camas and Portland - Vancouver areas.

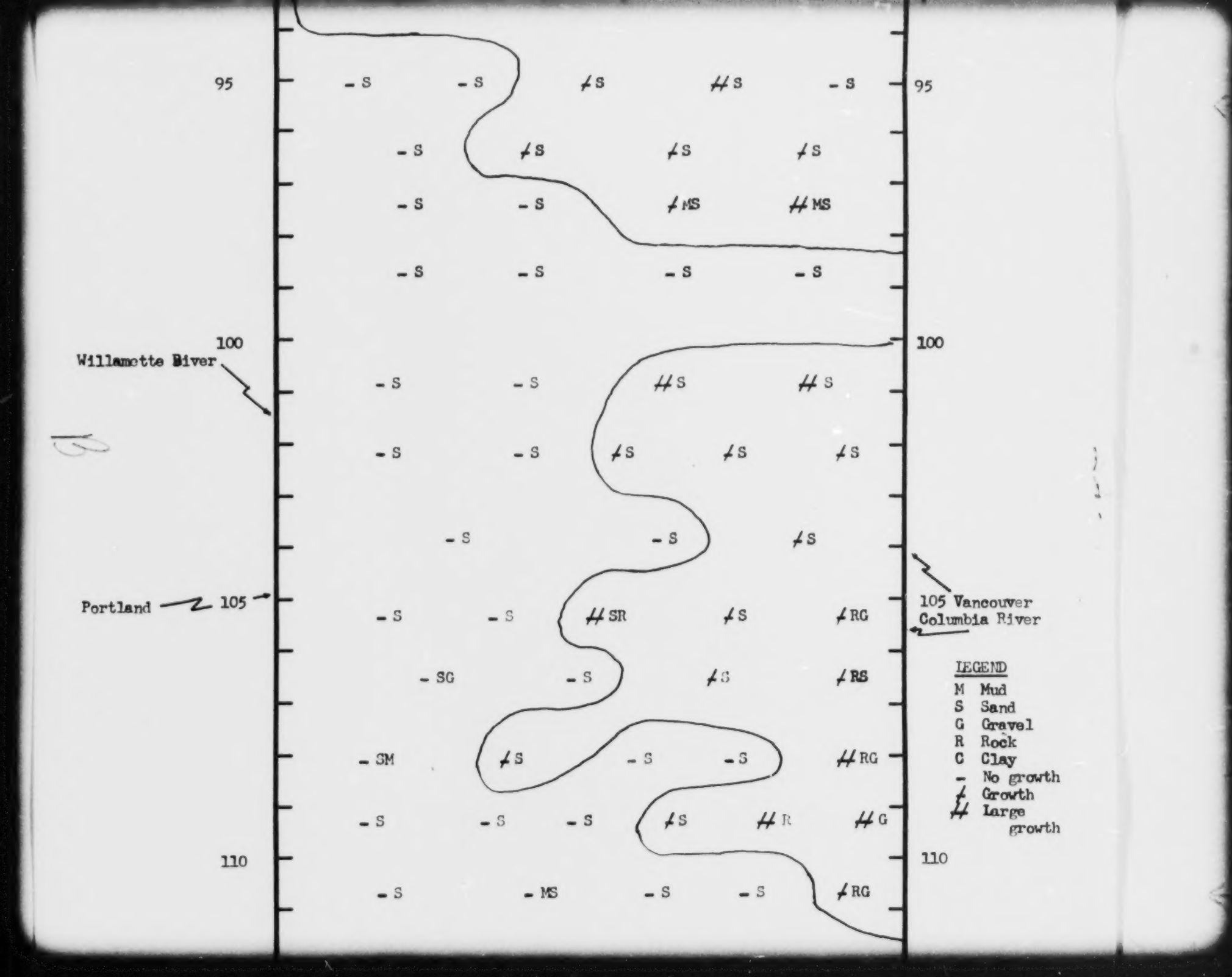
Bottom Sampling (See Appendix III)

Bottom samples were collected at 25 sections in the river between mile 121.8 and mile 87.4. From three to seven equispaced stations were sampled at each section. Each station was sampled a minimum of twice during the period from September 21 to October 20. On October 21 four additional sections of three to four stations each were sampled above 121.8 to mile 130.9. The data thus collected are shown on Fig. 1. This figure shows the character of the bottom and the magnitude of the growth. No scale was used in preparing the figure, although the river mileages are shown on the vertical.

The growth collected from the bottom and from the nets of fishermen was identified to be largely Sphaerotilus natans and especially the variety "prolifera." Difficulty was experienced in differentiating between live and dead organisms. Some live growth was observed without apparent attachment (in sand) and may have been transported from its growing bed. All samples showing growth were recorded.

It was not feasible to determine variations in river width, channel location, surface attachment objects, or distance between sections. A dividing line is shown between areas of no growth and those where growth was observed. It can be seen that no growth was recovered above Camas, Washington, and that the preponderance of samples showing growth were obtained from the Washington side.


RIVER MILES OREGON
85
St. Helens
90
95
RIVER WASHINGTON MILES
85
90
95
-R
≠S
//S
≠MS
-S
≠S
≠S
≠S
≠S
≠S
//RS
-S
-S
≠S
//S
-S
-S
≠S
≠S
≠S


95
100
105
110
Willamette River
Portland
105 Vancouver
Columbia River
LEGEND
M Mud
S Sand
G Gravel
R Rock
C Clay
- No growth
/ Growth
// Large growth

COLUMBIA RIVER STUDY
Sphaerotilus vs Type of Bottom
Sept.—Oct. 1955
FIGURE 1

Samples for Chemical Analysis

Samples were collected for Pearle-Benson index and sugar determinations along with the bottom samples. These samples were collected at a standard depth of 25 feet except when much deeper or shallower water made it necessary to vary the depth to take the sample within a few feet of the bottom.

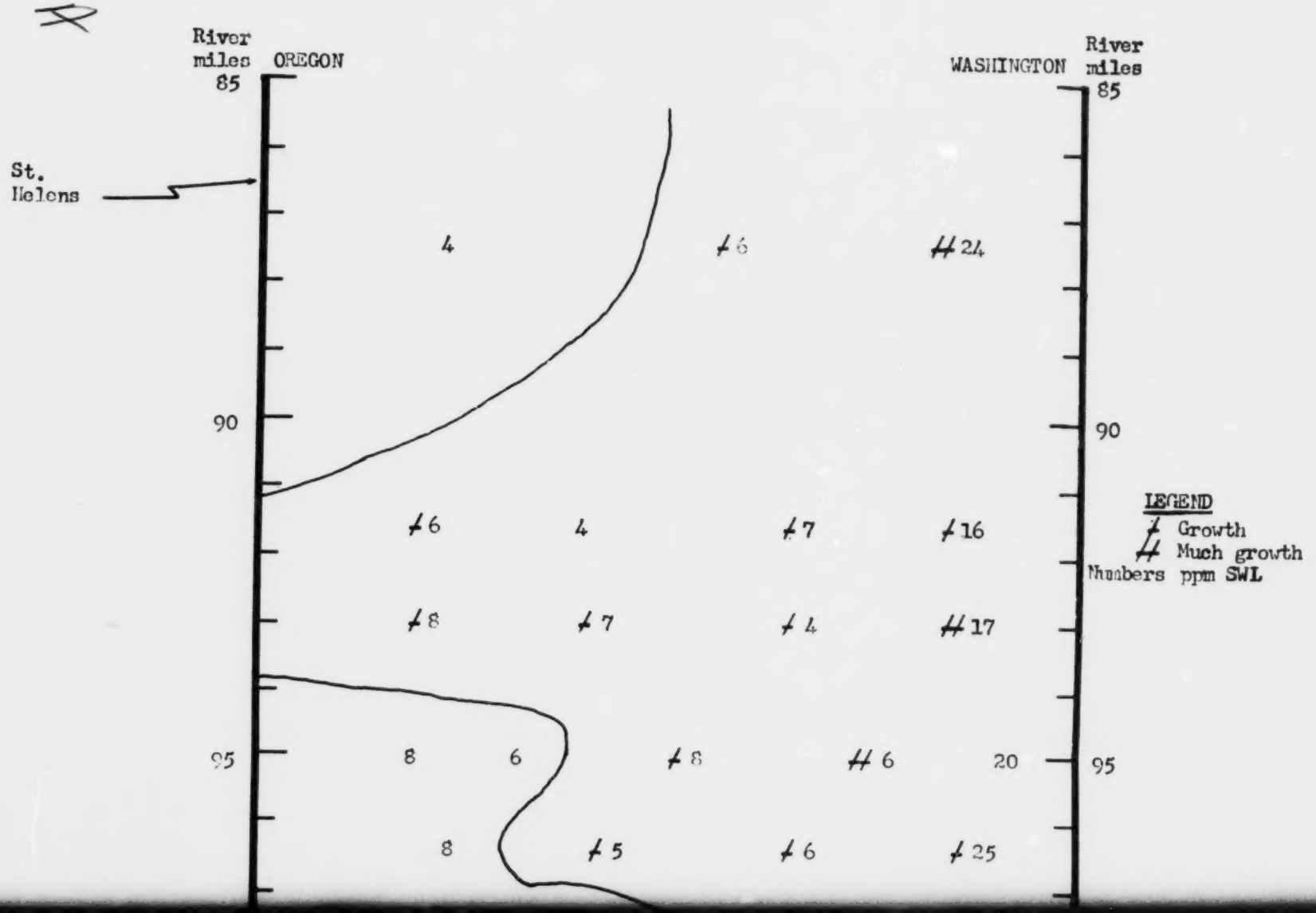
The Pearle-Benson test is a test for sulfonated lignins. Since these lignins are a major constituent of waste sulfite liquor from a sulfite pulp mill, the test indicates the apparent amount of liquor present in the sample. Sulfite waste liquor, however, contains sugars and other compounds. The lignin is the most stable of these constituents. The sugars especially are rapidly broken down or utilized by the biota of the river. For these reasons the Pearle-Benson test indicates only the lignin fraction of the waste. Other constituents will be considerably reduced in concentration depending upon the distance from the point of discharge. Its limitations should be recognized, therefore, in interpreting the results of the test. Despite its limitations it serves as a useful index of SWL concentration.

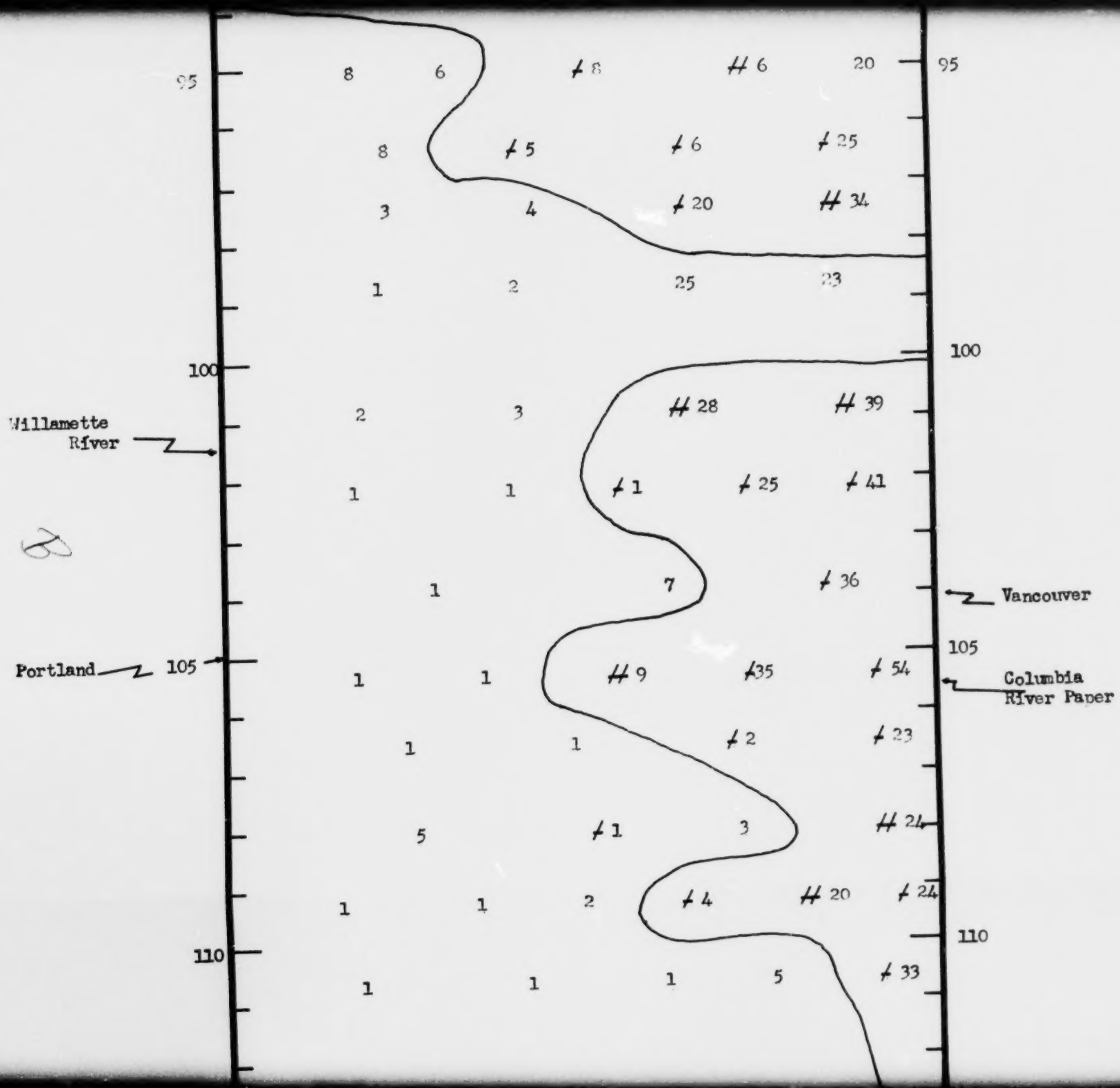
Results of SWL analyses are shown on Fig. 2. The stations were sampled at different times on different days over a period of approximately five weeks. Thirteen samples were collected on October 20 at the buoy anchored on section 117.1 between 10:15 a.m. and 4:15 p.m. at 30-minute intervals. These samples showed the following concentrations:

Maximum	58 ppm
Minimum	2 ppm
Range	56 ppm
Median	32 ppm
Mean	29 ppm

The considerable variation of sulfite waste liquor concentration at any point with time is thus illustrated. The data do appear sufficiently consistent, however, to indicate the pattern of SWL dispersion in the river.

It is to be noted that the general area of the river showing SWL concentrations of 10 ppm or more was generally along the Washington side and is coincident with the area in which growth was recovered. This is not considered sufficient evidence, however, to indicate that there is special significance to the 10 ppm concentration or that the presence of some specific concentration of SWL is associated with Sphaerotilus growth since growth has been found in lower concentrations.


River miles
OREGON
WASHINGTON
River miles
85
90
95
St. Helens
4
6
24
6
4
7
16
8
7
4
17
8
6
8
6
20
8
5
6
25
LEGEND
Growth
Much growth
Numbers ppm SWL


95
100
105
110
Willamette River
Portland
Vancouver
Columbia River Paper
8 6 8 6 20
8 5 6 25
3 4 20 34
1 2 25 23
2 3 28 39
1 1 1 25 41
1 7 36
1 1 9 35 54
1 1 2 23
5 1 3 24
1 1 2 4 20 24
1 1 1 5 33

COLUMBIA RIVER STUDY
Sphaerotilus vs SWL
Sept.—Oct. 1955
FIGURE 2

The theory that relatively low concentrations of SWL, combined with other necessary conditions, are associated with the presence of Sphaerotilus would seem to be reinforced. Comparatively few samples were collected which had a SWL concentration of 50 ppm or more. Areas with no or only trace amounts of SWL (barely detectable by the Pearle-Benson test) did not show the presence of Sphaerotilus.

A method for making sugar determinations was developed and is shown in Appendix IV.

Tile Boxes

During the study it was observed that the occurrence of growth depended not only on the presence of material in the water which supported the growth, but on suitable surfaces where the growth could attach. In order to eliminate the factor of availability of suitable existing surfaces from the study of the water conditions supporting growth, it appeared desirable to devise an artificial surface which could be moved to various locations. Such a surface should also allow a measurement of the magnitude of the growth and a comparison of this magnitude with the water quality conditions.

A number of types of devices were investigated which could be anchored to the bottom, which would provide a satisfactory attachment surface of inert material and which would permit the removal of the growth for identification and some sort of quantitative measurement. After several experiments and improvements a tile box was devised which proved to be satisfactory. These boxes were constructed locally and used throughout this study. Since this is a significant development of the study, a description of the boxes and the method of using them is given in Appendix III.

Stream Samples Collected at Tile Boxes

Stream samples were collected at each submerged device at the time of placement and at each sampling period. The results of samples taken at the four sections on October 20 are shown as an example of results obtained.

Buoy	Section	SWL (ppm)	Total Soluble Phosphate (ppm)	Total N (ppm)	Total Inorganic (ppm)	Total Organic N (ppm)	* Velocity (fps)
#1	121.0	21.0	.095	.444	.1	.344	1.06
3	119.6	21.0	.095	.444	.1	.344	2.08
5	118.8	16.0	.105	.436	.1	.336	1.64
6	117.1	17.0	.085	.452	.1	.352	1.67

*Obtained with Price current meter.

The Pearle-Benson test appears to be valuable in that it provides a means of classifying the environment with respect to sulfite pulp mill waste. It was recognized that other waste material may contribute to the growth. Velocity measurements were obtained, since it had been suggested that velocity may be an important factor in Sphaerotilus growth.

Much of the time devoted to the boxes during this period of the survey was consumed in the development and improvement of the device and method of uses. These boxes, however, proved invaluable during the periods which followed this initial development. Data obtained during these periods will be discussed later.

INTERIM PERIOD BETWEEN

FALL AND SPRING STUDIES

Studies in Period Between Fall and Spring

The period between the close of the first intensive phase of the cooperative study on the Columbia October 25, 1955 and the beginning of the second period of concentrated activity on March 20, 1956 was devoted largely to improvement of tile box design, construction of additional boxes, acquisition of anchoring equipment and some field activity when weather permitted.

The winter of 1955-56 was unusually wet and cold. The rains started in October and continued almost without interruption through the sampling period in April. Stream flows, as indicated in Figure 1 and Table 2, Appendix IV, were also unusually high. A freshet occurred in late December and, because of a spring flood which was predicted to achieve damaging proportions, Roosevelt Lake was drawn down sharply in March and early April to provide storage to absorb a part of the expected flood waters. This increased the discharge of waters through the area.

A severe cold wave in early November caused water temperatures to drop rapidly from 14 °C on October 26, 1955 to 4.5 °C on November 17. Another cold period in late January caused the Columbia to fill with blocks of ice and interfered seriously with operation of the tile box samplers.

Reference is made to Table 1, Appendix V, which shows results of tile box studies from above Camas to above Vancouver (miles 124.6 to 109.3). (See Maps, Appendix I). It will be noted that the control station (mile 124.6) showed small accumulations of Sphaerotilus and related organisms but volumes of growth were consistently less than 10% of the growth below Camas. This shows that seed organisms are present in the river above the control point. (Tile box at 124.6 was changed during the spring survey and its location is not shown on the Map).

At Station No. 7 (Hassalo Rock - mile 117.1, area where growths cause difficulties) and at mile 109.3 (Maoi Tug) considerable growth of Sphaerotilus was collected on November 2 and 9, 1955. On the former date, the accumulation at 109.3 was almost double the amount found at Station 7.

The results for December and January show that temperatures of 2 to 3 °C retard the growth of Sphaerotilus. Reference to the literature on physiology and ecology of Sphaerotilus indicates distinct retardation in water under 5 °C, according to Hohnl (4), under 4 °C, Liebmann (5) and below 6 °C for the Columbia River as found by Lincoln and Foster (1).

River studies were interrupted from the end of January to March 1 because of low water temperatures and to avoid additional losses of sampling equipment caused by ice movement.

MARCH AND APRIL

1956 STUDY

March and April, 1956 Study

Background

The fall 1955 survey was principally concerned with the development of procedures for the study of Sphaerotilus problem and to some extent the collection of control data. The spring study was intended to utilize the techniques developed for the collection of data. It was hoped that investigations during the period of heavy growth would provide the best conditions for delineating areas of active growth and for measuring growth with respect to environmental conditions. It was expected that the spring months would be periods of low flow and more favorable for the growth of Sphaerotilus. However, the low flows did not occur. The results demonstrate the variable character of the problem.

Table 2, Appendix V, gives the record of flows of the river from March 16 to April 17 inclusive.

Bottom Sampling

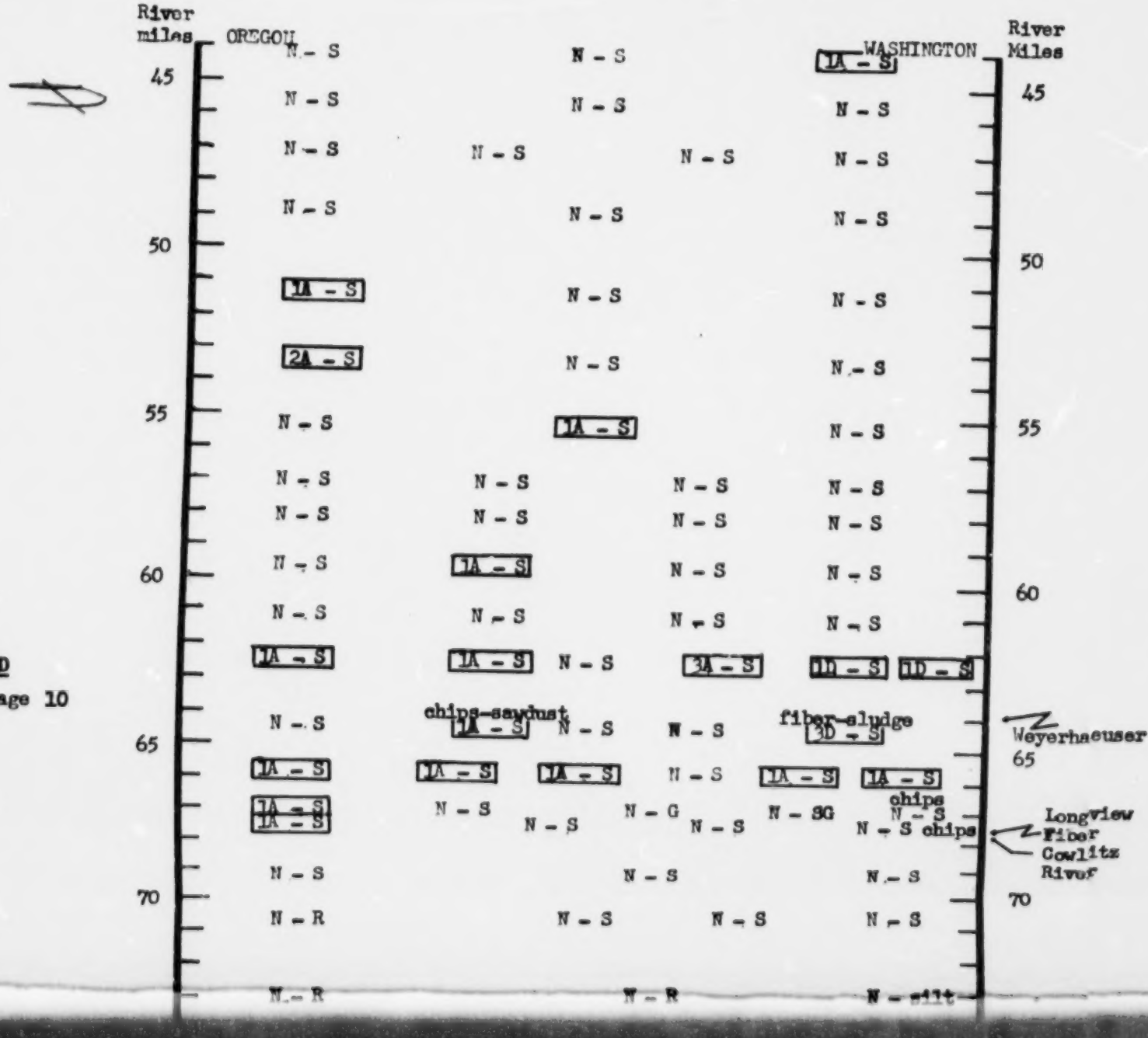
Bottom sampling with the trawl type sampler (Appendix III) was conducted from March 19 through the 21st, 1956. Samples were collected at 52 sections in a 78 mile stretch of river from Puget Island to above Camas. The sections were identified by the river mileage from the mouth. These are shown on the Columbia River Maps, Appendix I, and identified by description in Appendix II.

There were equispaced sampling stations in each section. The number of stations in a section was determined by the width of the river and proximity of pollution sources. The stations were numbered from the Oregon shore. Thus, 1 to 5 or 1/5 represents the station nearest to the Oregon shore of 5 equispaced sampling points.

Discussion of Bottom Sample Results

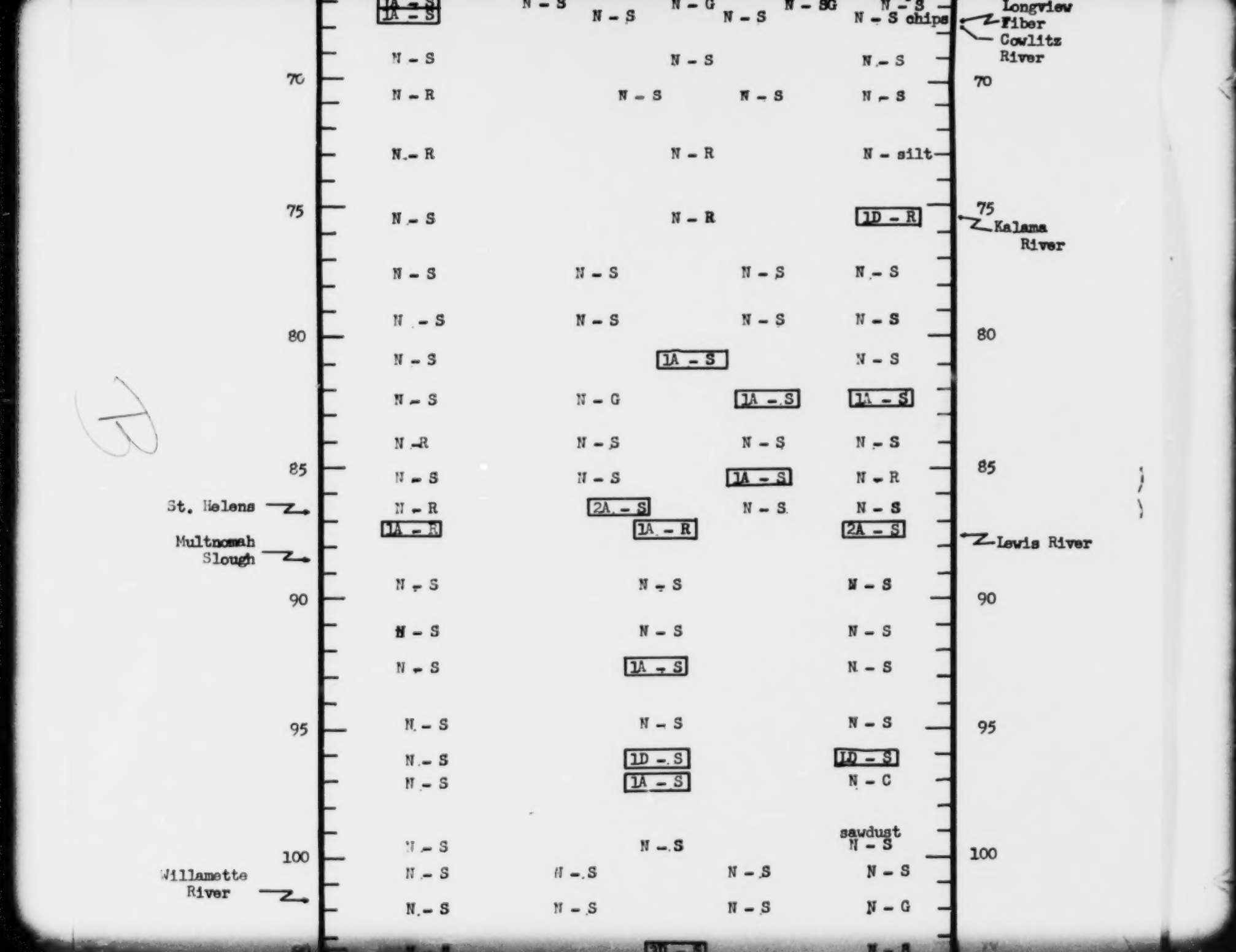
The results of a large number of bottom samples have been plotted on Figure 3. This figure represents the Columbia River between miles 44 and 124. The first letter or combination of number and letter indicates the extent of the growth. The second letter specifies the character of the bottom. The length of the stream is to scale, the width is not. The locations of samples which showed growth are emphasized.

Although the growth of Sphaerotilus was not prolific during this period, the locations where growth occurred are significant. It



LEGEND

See page 10


1A - S
N - S
N - G
N - S
N - SG
N - S
N - S chips
Longview Fiber
Cowlitz River
70
N - S
N - R
N - S
N - S
N - S
N - R
N - R
N - silt
75
N - S
N - R
1D - R
Kalama River
N - S
N - S
N - S
N - S
80
N - S
N - S
N - S
N - S
N - S
1A - S
N - S
N - G
1A - S
1A - S
N - R
N - S
N - S
N - S
85
N - S
N - S
1A - S
N - R
St. Helens
N - R
2A - S
N - S
N - S
1A - R
1A - R
2A - S
Lewis River
Multnomah Slough
N - S
N - S
N - S
90
N - S
N - S
N - S
N - S
1A - S
N - S
95
N - S
N - S
N - S
N - S
1D - S
1D - S
N - S
1A - S
N - C
sawdust
N - S
N - S
100
N - S
N - S
N - S
N - S
Willamette River
N - S
N - S
N - S
N - G

COLUMBIA RIVER STUDY

Sphaerotilus vs Type of Bottom

March — April 1956

FIGURE 3

appeared in the river immediately below Camas and remained near the Washington side until well below Vancouver. At the entrance of the Lewis River it seemed to spread toward the Oregon shore.

There was an area between mile 81 and the Longview area where no growth was found. Growth was again found at and below Longview. Tidal effect is responsible for the occurrence of growth throughout the width of the Columbia in the Longview area.

The growth as it appeared during this spring survey was materially less than that observed in the previous fall. Intensive bottom sampling was discontinued after the initial run which was made during March 19, 20 and 21.

Tile Box Samplers

Tile box samplers of the type described in the previous (Nov. 21, 1955) report were used to attempt to determine the relationship of Sphaerotilus growth to various environmental conditions. The Camas area was chosen as the principal study area. Thirteen of the 6-inch tile box samplers were placed in locations previously determined to provide a range of velocities and nutrient concentrations. A few smaller samplers containing 4-inch tile were placed in the Vancouver and Longview vicinities. The locations of the tile boxes are shown on the Columbia River Maps, Appendix I. Those in the Camas area are shown on pages 14 and 15 of these Maps. Those in the Vancouver area are shown on page 12 and in the Longview area on page 6 of these Maps.

Collection of Samples at Tile Boxes

Samples for chemical analysis were collected at tile box station 6 on Wednesdays and Fridays and at stations 7 through 12 on Mondays and Thursdays from March 28 to April 16, 1956, inclusive. Chemical samples consisted of composites of eight individual samples collected at approximately half hour intervals between 9:00 and 1:00 P.M. on the dates indicated. Velocity measurements by Gurley current meter were made on three different days during the period of sampling at all the tile box stations. All growth sampling was done on Tuesdays during the sampling period and performed as outlined in the report of the September-October study. The chemical analyses were all performed as described in Appendix IV or according to Standard Methods for the "Examination of Water, Sewage and Industrial Wastes" (7) 10th Ed.

Table 3, Appendix V, gives the results of the chemical analysis of samples collected. This table shows the results of the tests for sulfite waste liquor (Pearle-Benson), carbohydrates, chemical oxygen

demand, biochemical oxygen demand and chlorides. Temperatures in degrees Centigrade and velocity in feet per second are also shown. The river flows for the period are shown in Table 2, Appendix V.

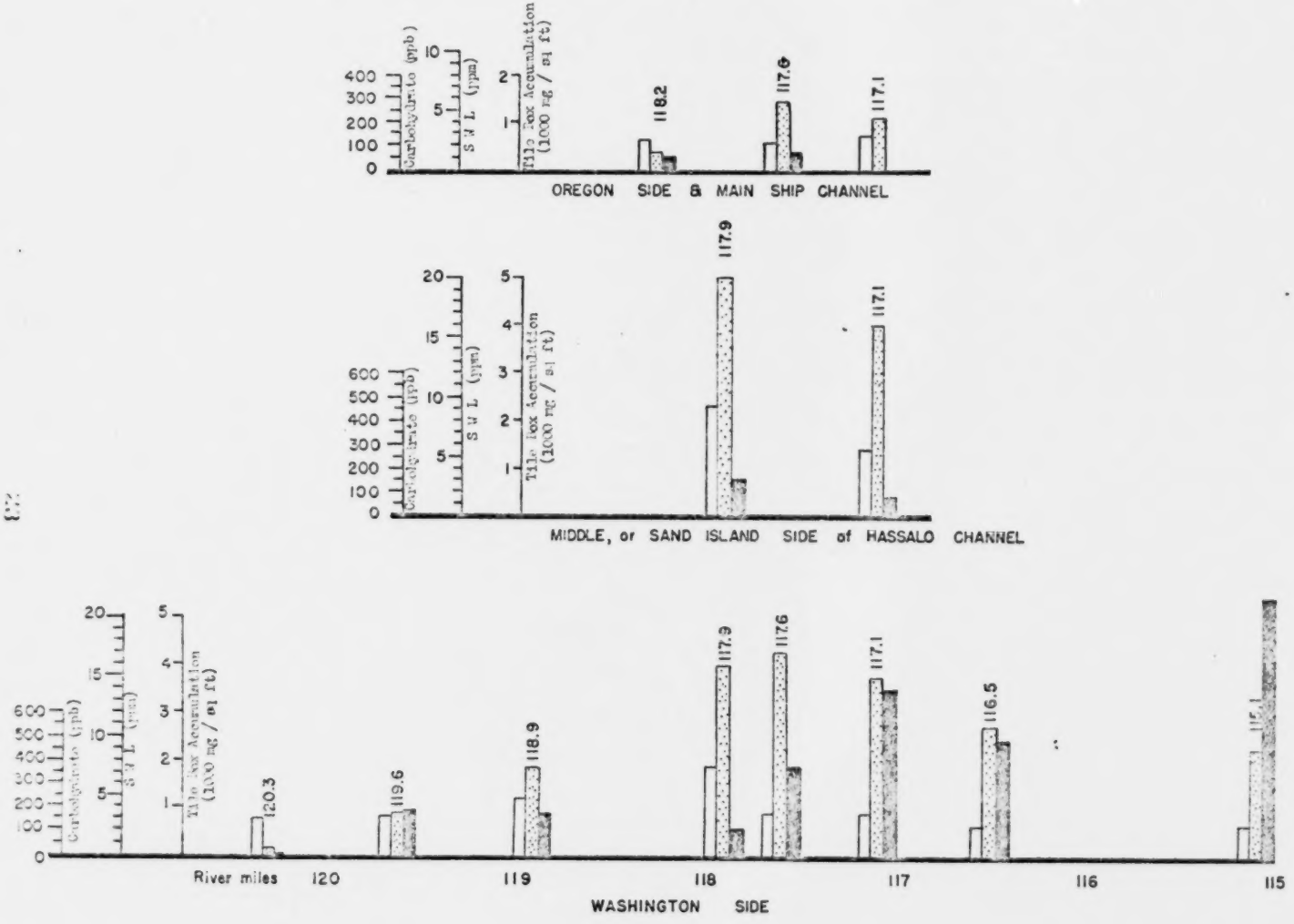
Tiles were removed from the boxes located between mile 115 and mile 120 at the end of one, two and three-week periods, the growth removed and measured. The results of these tests are shown in Tables 4, 5, and 6 respectively. The total accumulation is reported as "total solids" and the organic material as "volatile solids". An examination was made of this accumulation and the comparative amount of Sphaerotilus and associated slime organisms was determined by microscopic examination.

The results in Table 2, Appendix V, show that the flow was high (200,000 to 300,000 cfs) over the entire period. This accounts for the comparatively low concentrations of sulfite waste liquor. Figures 4 and 5 were prepared to compare the results of the chemical and growth test results. Figure 4 shows the results obtained from the exposure of tiles over a three-week period, from March 27 to April 17. The average of 2 to 5 sets of chemical results were used in preparing this chart. Figure 5 shows the results of one-week's exposure (April 10 to 17) correlated with one or two sets of chemical data.

The control station at mile 120.3, which is immediately upstream from the principal sources of waste discharges at Camas, shows that low concentrations of carbohydrates and sulfo-lignins are normally present in the river. These may be considered as background concentrations, just as the traces of Sphaerotilus present at this station indicate the normally expected background for this organism.

Both charts show the increase of accumulated slimes below Camas. This accumulation on the tiles, including Sphaerotilus, is related to increases in carbohybrates and sulfite waste liquor. At mile 116.1 below Camas the amount was 1000 to 2500 mg per square foot. The greatest accumulations occurred along the Washington side of the river and increased sharply at mile 115.1 to more than 5000 mg per square foot.

Two sampling stations showed a negative correlation between the amount of accumulation and the chemical results. The growth did not respond to the high nutrient concentration due to adverse physical conditions of these two stations. At mile 118.0 station "sand blasting" action prevented the material from accumulating. The tile box at this location was anchored in shallow swift water over a shifting sand bottom. At mile 117.1 station there was excessive turbulence around the tile box which was anchored to the buoy on Hassalo Rock. Current velocities at this point averaged four feet per second which was excessive when compared to those at other stations where the velocity was 1 to 3 ft. per second.



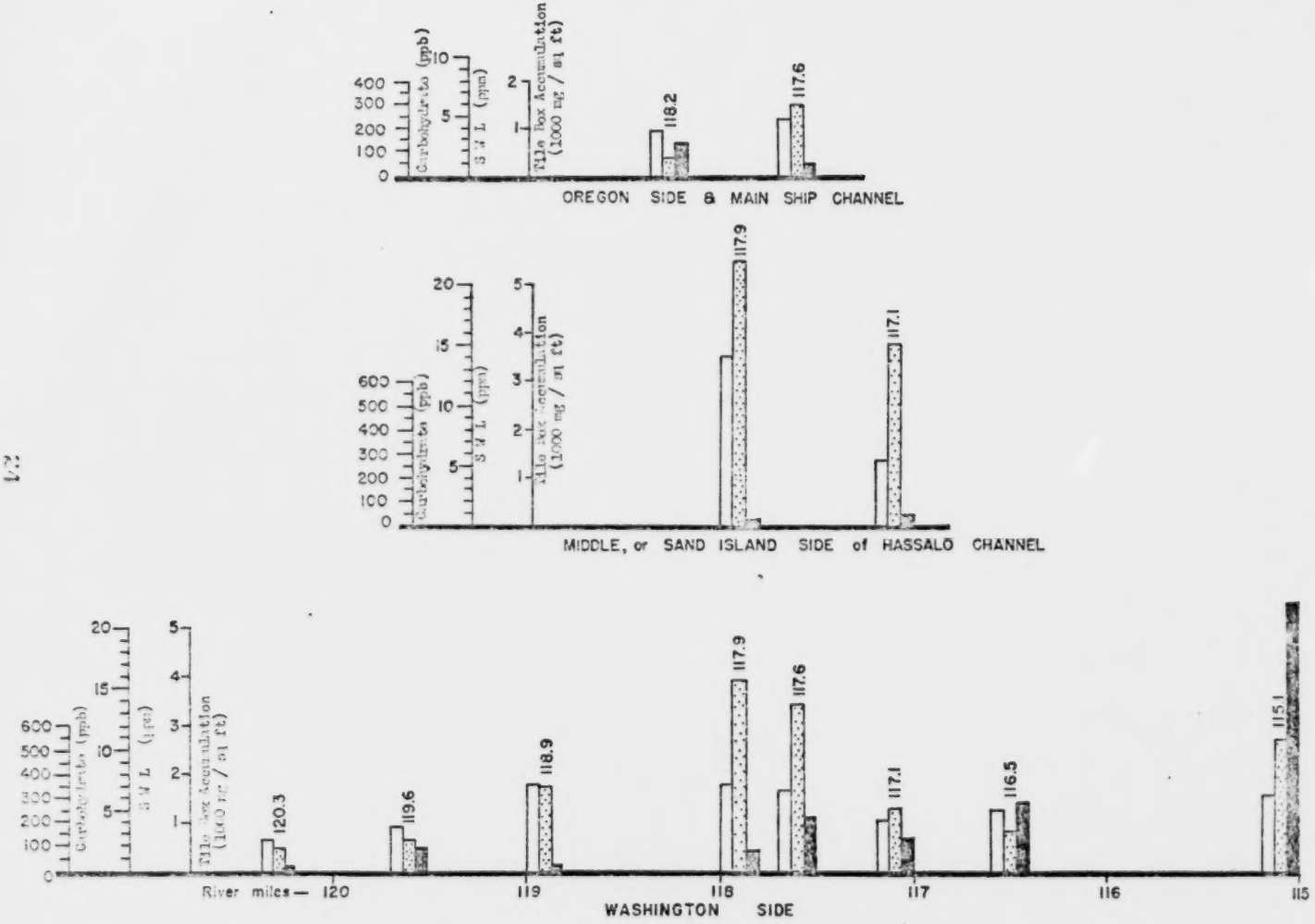
COLUMBIA RIVER STUDY

Accumulation on Tile vs Carbohydrate and Sulfite Waste Liquor

March 27— April 17

1956

FIGURE 4



COLUMBIA RIVER STUDY

Accumulation on Tile vs Carbohydrate and Sulfite Waste Liquor

April 10-17, 1956

FIGURE 5

The results of the test made at tile boxes located near the Oregon side of the river and in the main ship channel, mile 118.3 to mile 117.1, indicate low concentrations of carbohydrate and sulfite waste liquor accompanied by small accumulations of growth on the tile.

Table 7, Appendix V, shows the comparative magnitude of accumulations on the tiles of boxes located in the Portland-Vancouver and Longview areas. (See maps in Appendix I for location of boxes).

Tiles exposed for one-week at station VRRB at the Interstate Bridge and in the vicinity of Vancouver waste discharges showed almost twice the accumulation as obtained at the Coast Guard station CG which is above these sources. However, the tiles sampled after 2 weeks of exposure showed little difference (1503 mg per square foot at station CG as compared with 1571 at station VRRB).

Turbulence prevented station D52 from being a satisfactory sampling point.

Accumulation at station LLB which was upstream from the Mouth of Cowlitz River and above Longview was 47 mg per square foot, 17 mg of which was estimated to be Sphaerotilus and associated slime. This was much greater than that found at any time above Camas; therefore, instead of normal "background", the growth at this point represents residual effect of growth-promoting nutrients from the areas upstream caused by prevailing low temperatures. The total mileage traversed by these nutrients ranges from twenty to fifty-three miles.

The moderately high accumulation of material on the tile at station LB, 2141 mg./sq.ft. tile, is attributed to localized nutrient sources along the Longview waterfront.

The location of station DBL was in a section of the river which was downstream from all pollution sources at Longview but yet not far enough down to provide complete mixing with the entire Columbia flowage. Nevertheless, the accumulation on the tile was only slightly more than one-half that found immediately above Vancouver (856 vs. 1503 milligrams per square foot) and only about one-fifth as great as at a number of points below Camas.

STUDIES ON LOWER WILLAMETTE RIVER

MAY, 1956 TO JUNE, 1957

Studies on the Lower Willamette River, 1956-1957

Background

The report of Lincoln and Foster on the Lower Columbia River in 1943 referred to the impact of heavily polluted water from the Willamette River upon the Columbia. A five-year cleanup program on the Willamette River in 1951-1956 provided an improvement in the quality (dissolved oxygen) of the Willamette River water. However, population and industrial expansion in the valley has almost kept pace with the program and the improvement was not as great as anticipated.

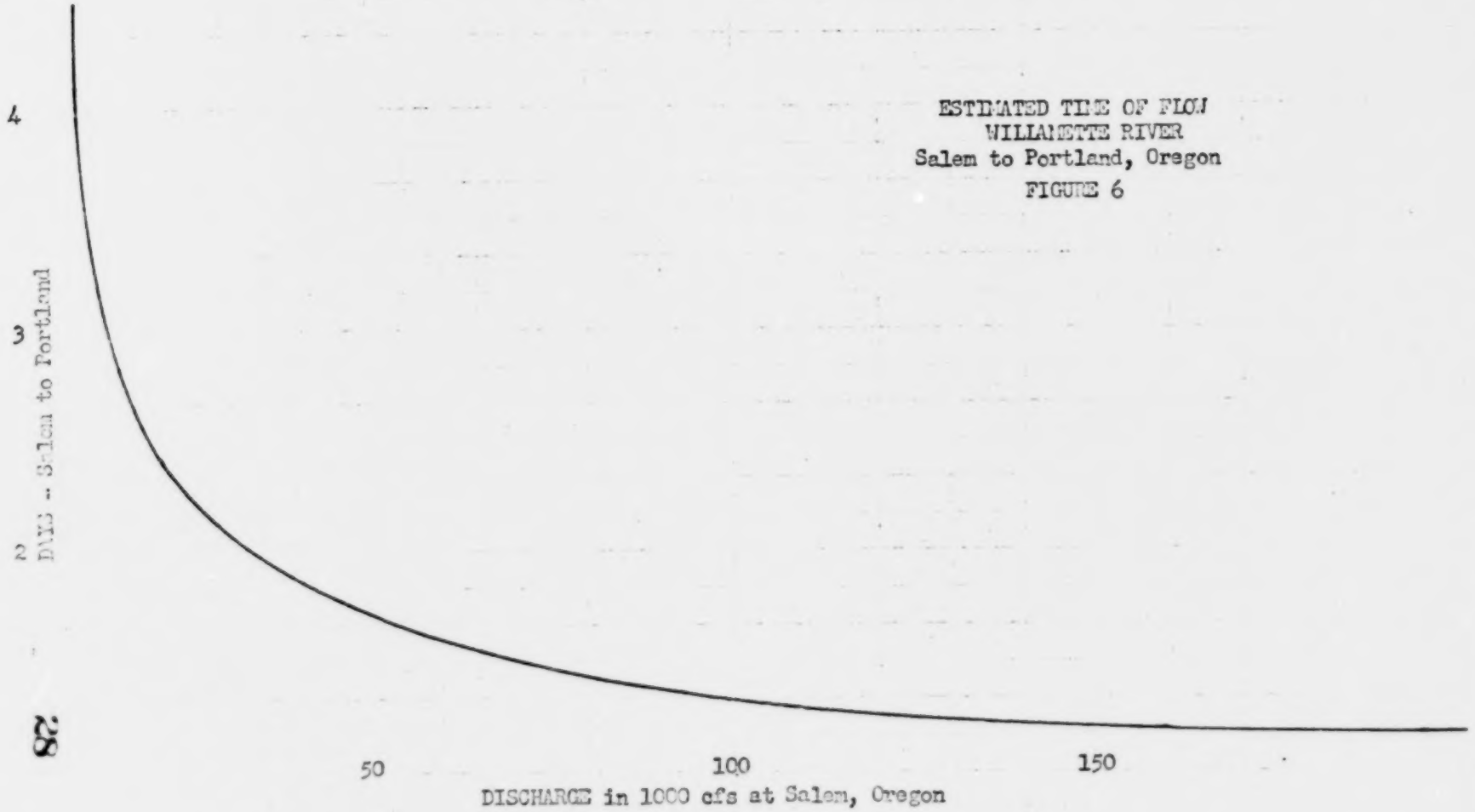
Two elements of the cleanup program actually resulted in increases in the pollutional load going directly to the Columbia River, (1) Raw sewage was intercepted along the Portland waterfront of the Willamette and transported to the new primary sewage treatment plant in north Portland from which the effluent is discharged directly into the Columbia River. (2) Concentrated sulfite waste liquor is barged from a pulp mill in Oregon City to the Columbia River where it is discharged at mile 99, below Vancouver. The latter procedure is employed normally from July 1 to November 1 each year.

In order to determine the contribution of the Willamette River to the Sphaerotilus problem of the Columbia, a study was initiated in the Lower Willamette over an annual cycle (June 1956 to May 1957). The field and microscopic analyses have been carried out by the Public Health Service. The Oregon State Sanitary Authority performed the laboratory analyses on the samples and assisted with some of the field work. (See Map, Figure 8).

Table 8, Appendix V, gives the stream flows as recorded at Salem and a graph figure 6 presents a basis for estimating time of flow from Salem to Columbia River at or near flood stage. (See Page)

Tables 9 through 13 , Appendix V, present the results of the tile box studies in this area. The stations where tile box samplers were anchored are described as follows:

Station	River Miles Above Willamette Mouth	Description
Marina Mart	28	Newberg Pool, two miles above Willamette Falls, upstream control
Sporteraft	25.5	E st side of river channel & one-half mile below Willamette F lls, Oregon City



ESTIMATED TIME OF FLOW
WILLAMETTE RIVER
Salem to Portland, Oregon
FIGURE 6

Station	River Miles Above Willamette Mouth	Description
East Portland Marina	12.8	East side of Portland's waterfront, immediately above Morrison Bridge
Columbia Tug Boat Co.	7.3	East of channel and above Spokane, Portland & Seattle Railroad Bridge
Gays Moorage	2.5	One-quarter mile downstream from the upper end of Multnomah Channel. This is not the main ship channel of the Willamette, but is representative of Willamette flowage except when the Columbia is in flood.

Table 9, Appendix V, Marina Mart, includes data for a single month (April 1957) at a time when temperature conditions were optimum for slime in the lower river. The results indicate accumulation similar in quantity to some of the less favorable situations below sources of pollution on the Columbia, however, qualitatively the growth was of different composition. The principal constituents of the material were organisms other than Sphaerotilus, such as diatoms, green algae and protozoa.

Table 10, Appendix V, indicates that total accumulations below Oregon City average close to the highest determinations below Camas or Portland - Vancouver, but content of volatile solids and Sphaerotilus exceeds any sample from the Columbia River by as much as 5 times. The total material accumulated was 8094 mg/sq. ft. of which 2198 mg was volatile solids. This amounts to 169 mg/sq. ft. of volatile solids accumulated each day, 50 percent of which was Sphaerotilus. (See Appendix III)

Table 11, Appendix V, shows the results from the station in Portland Harbor, immediately above Morrison Bridge. Although the pulp mills impound their strong liquors or barge them to the Columbia during periods of low flow in the Willamette, the results indicate concentrations of SWL in excess of 100 ppm at this station on seven occasions in August and September. The effect of pulp mill and other wastes as growth promoters is shown in the tile accumulations. However, the heaviest daily rate of accumulation occurred after November 1 which was the end of the period during which waste was pumped to the holding ponds. (These mills hold wastes in ponds during the summer period and discharge during winter freshets). Rates of growth and percent of Sphaerotilus was less than that which occurred at Sporterraft. (See Page) Other sewage bacteria and fungi mingle with the Sphaerotilus in increasing proportion as the river proceeds through Portland Harbor to the Columbia (Appendix V).

This tendency for growth of mixed slime populations increases especially in summer as the river flows down through the harbor to the Columbia to the Tug Boat Station (above St. John's Bridge) and to the upper end of Sauvies Island (Gays Moorage). This is a period when flows are low, high water in the Columbia backs up into Portland Harbor and pulp mills impound their strong liquors. Tables 12 and 13, Appendix V, show that the percentage by volume of Sphaerotilus falls off markedly in summer at these lower stations.

As the Willamette flows increase in late fall, pulp mills cease impoundment of their wastes and discharge directly into the river. Temperatures dropped, thereby retarding most bacterial growth except Sphaerotilus which shows a marked increase (See page). Important also to the encouragement of Sphaerotilus is the positive current through Portland Harbor during most of the winter months with the resulting rapid transfer of nutrients from upstream sources down through the harbor. Although silt in suspension during sharp freshets interferes with slime formation, conditions are favorable at most times during the winter for growth throughout the Lower Willamette. In past years the Oregon State Sanitary Authority has received complaints from the owners of one of the steam power plants located along the Portland waterfront. Investigations revealed that intake screens were clogged with large masses of slime which had been washed down by high water from upstream growing areas. These complaints were received only during period of first freshet in late fall or early winter.

In addition, freshets lift and transport to the Columbia deposits of slime, wood fibers and other sludge material which are known to settle throughout Portland Harbor during low flow periods. Tests with tow nets have been made on two occasions to demonstrate that slimes and other suspended matter settle in upper Portland Harbor during periods of medium to low flow(7000 to 20,000 cfs). and that freshets lift and transport these slimes to the Columbia River.

Tests of the sedimentation of suspended slimes into upper Portland Harbor were made on May 10 &1[illegible], 1956 when flows at Salem averaged 35,000 cubic feet per second. A cheesecloth conical net with 17-inch diameter opening was operated as a vertical tow net from the bottom of the river to the surface at a number of stations from Oregon City to Steel Bridge in Portland. The volume of material collected was determined by sedimentation in a liter graduate and calculated to milliliters per cubic meter of river water. Microscopic examination revealed a mixture of wood fibers, miscellaneous detritus and a consistently high percentage of Sphaerotilus with associated slime organisms. The following tabulation shows the tendency for this suspended matter to settle in upper Portland Harbor under the existing conditions of flow.

Station	River Mile	River Depth in Feet	Distance of Vertical t w (feet)	Catch in Ml/cu. ft.
Oregon City	25.8	120	30	1.6
Rock Point	24.0	72	60	1.7
Oswego	21.0	58	50	.83
Waverly	18.0	54	45	.83
Oaks Park	16.0	48	48	1.7
Ross Island Bridge	14.0	42	42	.24
Steel Bridge	12.0	90	74	.54

The flushing action of freshets in the Lower Willamette has been investigated several times in recent years. One of the more conclusive tests was made on December 21, 1957 as the river was rising toward a crest of more than 150,000 c.f.s. Tow net hauls were made at two locations: (1) the mouth of the Willamette and (2) in the Willamette flow of the Columbia at a point one-quarter of a mile below the confluence. A Keighard silk tow net (Appendix III) with a one square-foot opening and 16-mesh cloth was used. The weight of material collected was determined for a given quantity of water passing through the net. The proportion of slime was determined by a microscopic differentiation of slime organisms from silt, debris and pulp fibers.

From these results it was estimated that a total of 2,200 tons per day of suspended matter of which 400 tons was slime passed the first location. The quantity passing the second location was 2940 tons and 980 tons per day respectively.

Under high magnification, the slime appeared to be the same type as that which originates in the Columbia, however, owing to the turbulence of the flood and abrasive action of silt in suspension, the material was more finely divided than slime immediately below growing areas in the Columbia River.

REPORTS OF COMMERCIAL FISHERMEN'S COMMENTS

Reports of Commercial Fishermen

A major difficulty experienced during these studies was that of coordinating the time when the growth in the river was at its maximum with the availability of manpower and equipment for the surveys. In order to schedule personnel and equipment, it was necessary to make preliminary arrangements for the more concentrated studies such as were carried out in the fall of 1955 and spring of 1956. In both of these cases it happened weather and stream flow conditions were not favorable and growth was not at its maximum.

Reports of fishermen who had almost continuous contact with the river were valuable indicators of conditions. Questionnaires were circulated to commercial fishermen who were operating on the various drifts of the river. The results are shown in the following tabulation. They extend over the period from February 27 to July 17, 1956. Most of the reports were received during July.

DATE OF OBSERVATION 1956	NAME OF DRIFT	APPEARANCE OF GROWTH	AMOUNT OF GROWTH
2-27	Wallace Slough	Light brown, fluffy	Moderate, heavy at times
3-2	Eddy Tank	Light Brown, fluffy	Heavy
3-5	Svenson	Brown, fluffy & gray, fibrous	Moderate to Heavy
3-5	Middle Channel	Light brown, fluffy	Heavy
3-6	Middle Channel	Light brown, fluffy	Heavy
3-9	Eagle Cliff & Wallace Island	Both light & dark	Variable to extremely Heavy
3-10	Oak Point	Light Brown, fluffy	Variable to extremely Heavy
5-10	Fashion Reef Channel	Light Brown	Light in volume, clumps of river silt mixed in
5-29	Newlett, Wn. side	Light brown, fluffy	Occasional clumps
7-2	Bachelor Island*	Brown, slimy	Heavy, getting worse
7-2	Newlett*	Both light & dark kinds	Heavy

*Washington edge of main ship channel

DATE OF OBSERVATION 1956	NAME OF DRIFT	APPEARANCE OF GROWTH	AMOUNT OF GROWTH
7-3	Above Milkmaid*	Dark Brown, fluffy	Heavy on top & bottom also
7-4	Milkmaid*	Light Brown, fluffy	Heavy for this stage of the river, 15 ft.
7-5	Outer Nigger Creek	Brown & slimy	Rotted net in four days started to get heavy
7-8	Eagle Cliff Wallace Slough	Green Slime	Extremely heavy
7-10	Newlett*	Light Brown, fluffy	Extremely heavy
7-12	Newlett*	Light Brown, fluffy & some dark, full of silt	Getting heavier every day
7-13	Newlett*	Light Brown, fluffy & some dark, full of silt	Heavy to extremely heavy
7-14	Eagle Cliff	Brown, fluffy	Heavily loaded & full of clumps
7-15	Wauna	Slimy, full of sand & silt	Fish moving back downstream Extremely heavy
7-17	Eagle Cliff	Light Brown fluffy	Extremely heavy

*Washington edge of main ship channel

Reports of Damages

Many reports of damages caused by the slime growths in the Lower Columbia and Willamette Rivers have been made to pollution control agencies by commercial and sports fishermen and others over the past 15 to 20 years. From these reports and observations of control agencies, it is apparent that the major damage is to commercial fishing. Drift nets collect large masses of wet slimy material which cling to the net making it necessary to dry the net before it can be removed and another drift made. Fishermen may make several drifts before leaving the river and limiting the operations to one not only decreases the chances of a catch but adds to the cost. The number of fish caught in a net covered with slime is also decreased since apparently the net is much more visible and does not fish properly because of the added weight. Reports have also indicated that the slime causes deterioration of nets decreasing their life. Many commercial fishermen report that they have given up fishing on the river due to the difficulties encountered with the slime. Documentary evidence for three such cases is available.

There are two principal kinds of tangible loss to fishermen occasioned by the slime in their nets: (1) Failure of nets to fish properly at a time when a run is heavy. For example, Mr. L. Anundi, Caples Duft below St. Helens, Oregon, reported that during the excellent fishing season of May 1955, he alone caught three tons of chinook salmon in the first five days of the season, when a freshet caused large masses of slime to move down river into the waters of his drift and all but prevented any further success in fishing. He estimated that he could have doubled his take that season, were it not for the slime. (2) Alleged shortened life of even nylon nets. Mr. Theodore Farnsworth of Vancouver Drift mile 102 to 103.8 claims that he fished a new nylon net less than six months in 1957 and had the webbing so weakened that he was forced to replace it at a cost of $1600 before the next season. With reasonable care, a nylon net should last about five years.

Sports fishing activity is reported to be seriously affected at many points (ten or more) on the Columbia River and also on the Lower Willamette River. Fouling of lures, fish lines, guides and reels has interfered with fishing success and the recreational value of many fishing areas along the rivers has decreased. This represents an economic loss.

People occupying riverside homes and boathouses and operating yacht clubs, moorages and commercial concerns have complained bitterly of conditions caused by the slime. Cables, tie lines, boat hulls and docks are reported to be fouled with the material.

DISCUSSION

Magnitude of the Problem

Through the use of tile box samplers, the Reighard tow net and bottom trawl, areas of active Sphaerotilus growth and distribution of dislodged growth downstream from growing areas in the Lower Columbia River and the lower 26 miles of the Willamette River were determined. The first two devices provided semi-quantitative results. The results of the use of the bottom trawl were qualitative and were used for purpose of estimating conditions existing in the river bottom.

In order to gain some understanding of the magnitude of the problem, the following calculations have been made based on the results of the tile box studies. In making these calculations it is realized that all bottom surfaces are not suitable attachment surfaces for the slime growth. Many samples from tiles had a dry weight of one gram or more per square foot. Several exceeded five grams per square foot. A gill net 1200 feet long, drifting downstream 1 mile will pass over an area of over 6 million square feet. Assuming a growth of 1 gram (dry weight) per square foot, the quantity of growth in this area would be over 7 tons. This does not take into account any slime which may be carried by the current into the drift from upstream growing sources or the Sphaerotilus which grows on suspended matter in the water. It is therefore possible that some of the damage to fishermen's nets may be caused by sheer mass of slime and resistance to current by the slime material.

With further reference to distribution downstream, both of active growing areas and of dislodged growth, the result from the tile box anchored for a short time above all sources of waste at Longview (LLB, Table 7) shows 47 milligrams (.047 grams) total accumulation per square foot. This station is situated more than thirty miles downstream from the Portland-Vancouver area, still the amount of growth found would produce up to 650 pounds of slime material in the area of the drift previously discussed. Again, no allowance is made for material washed down from growing areas upstream.

If growth of the magnitude found during these studies occurred in 1955-56, a comparatively poor growing year, it is logical to assume that heavier growths are to be expected in more favorable years such as 1957-58. This had indeed been bourne out by reports of experiences by fishermen in 1957-1958 which have been substantiated by reconnaissance of the investigators. The unusual severity of the problem in late 1957 and early 1958 in comparison with the 1955-56 season is attributed to the characteristics of flow in the Columbia. Reference to Figure 7 indicates comparative river flows at The Dalles for these years. It is noted that a strong freshet occurred in late December, 1955, which flushed the growth to the sea from the entire lower river. For the remainder of that water year, 1956 until the principal freshet in early June, flows averaged higher than in the year 1957-58.

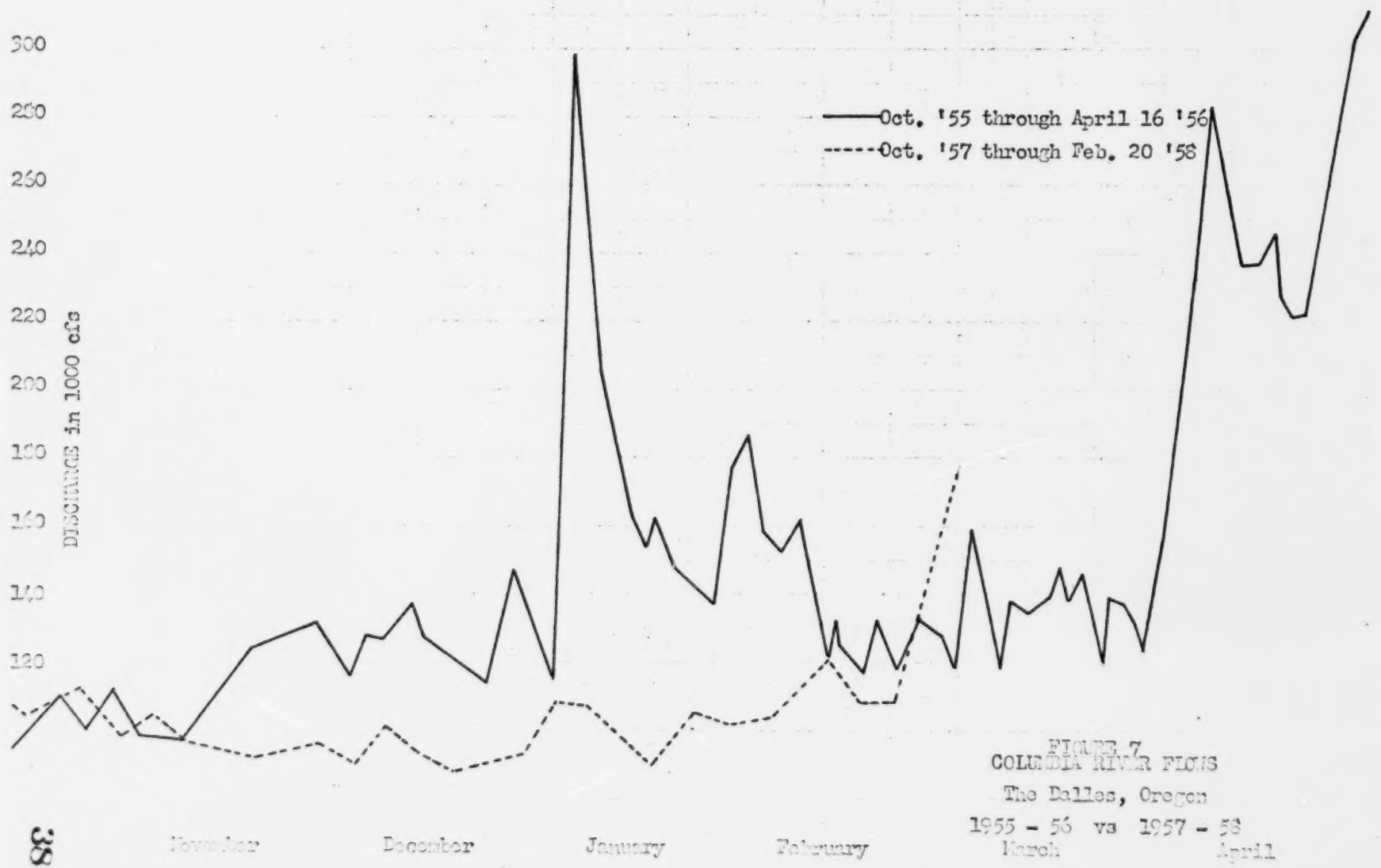


FIGURE 7
COLUMBIA RIVER FLOWS
The Dalles, Oregon
1955 - 56 vs 1957 - 58

The long period of low water in the Columbia throughout the fall and early winter of 1957-58, coupled with water temperatures that averaged between 3 and 6 degrees centigrade (2 degrees higher than 1955-56), apparently extended the growing area to a great distance downstream. Then, with the freshet starting in late January into February, growths dislodged in masses and were reported in nuisance amounts all the way to Astoria. At Skamokawa, Washington, about thirty miles above the Mouth of the Columbia, fishermen in February 1958 were forced to wash their nets thoroughly after every drift. Most of the slime material was observed to be in small masses and loaded with silt and wood fibers, which indicates travel over long distances. This was the same type of slime which was found to be discharging from the Willamette into the Columbia during the December 1957 freshet in the Willamette.

Physical and Chemical Factors

Within the range of temperature normally encountered in the rivers under study, there appears to be no limitation on growth exerted directly by temperature except in the very low range of 0 degrees - 3 degrees. The interim studies between fall '55 and Spring '56 showed a sharp decline in growth on the tiles at temperatures under 3 degrees C. In the range of 5 degrees - 10 degrees, which exists in late fall and early spring in the Columbia and Willamette Rivers, conditions are ideal for growth over long reaches of the river, provided that flows remain moderately low.

Tile Boxes in the Willamette showed active Sphaerotilus growth throughout the length of the lower river during the late fall, winter and early spring except as interrupted by high water. During late spring to early fall a combination of the following factors tended to restrict growth of Sphaerotilus in the river from Oregon City to Oswego or Waverly (Miles 25.8 - about 20):

(1) Other bacteria in the higher temperature range competing for nutrients at expense of Sphaerotilus.

(2) Impoundment or barging of strong liquors by the pulp mills, which reduced the concentration of nutrients during that period.

(3) Lower stream flows which lengthened time-of-flow through Portland Harbor and allowed more time for removal of nutrients by competing organisms.

The period of intensive investigation in the Columbia did not extend throughout an entire year; therefore, interpretations of the kind employed on the Willamette are limited. However, field reconnaissance over the past four years on the Columbia River has corroborated the findings on the Willamette River.

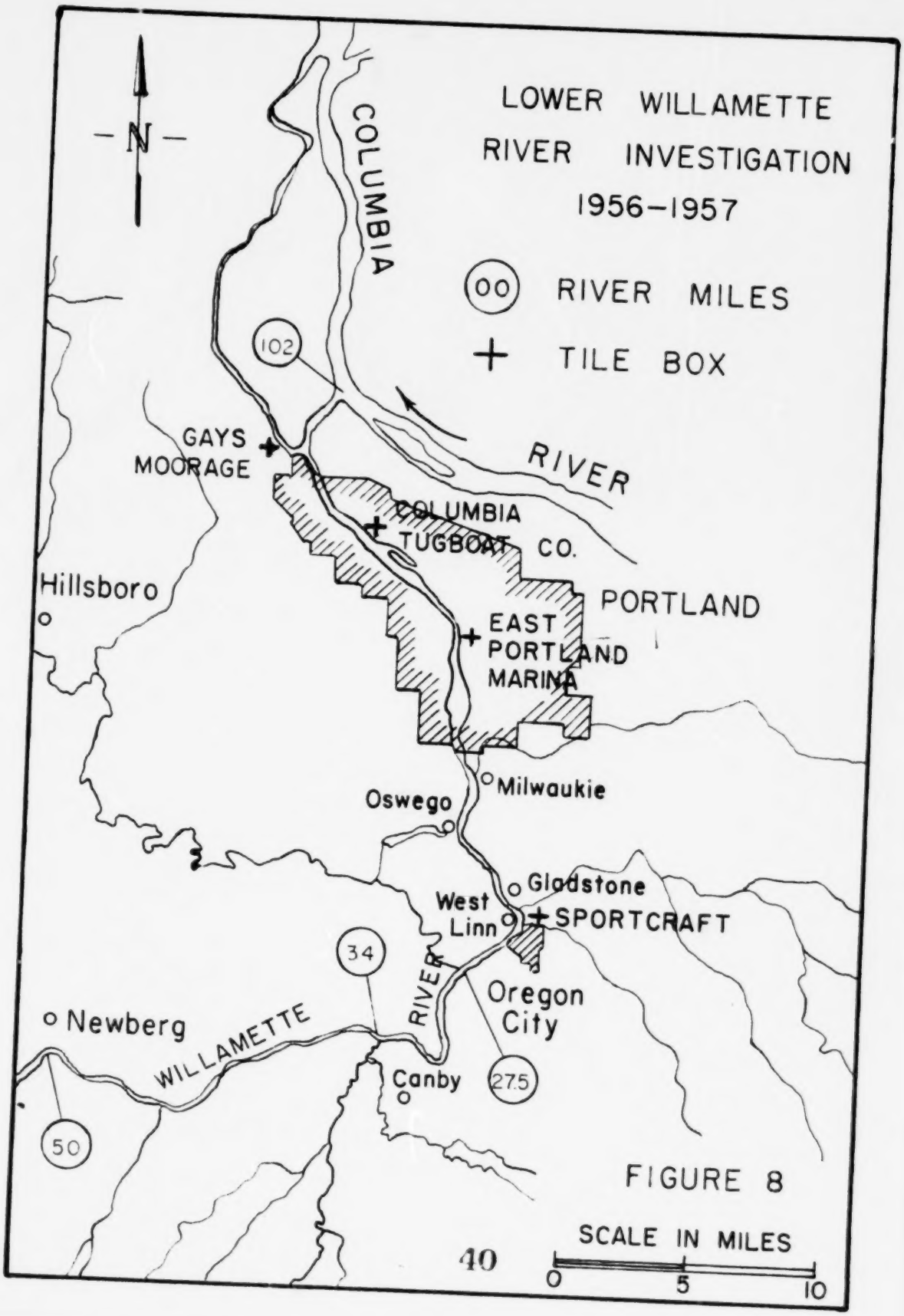

LOWER WILLAMETTE
RIVER INVESTIGATION
1956–1957
00 RIVER MILES
TILE BOX
N
COLUMBIA
RIVER
102
GAYS
MOORAGE
COLUMBIA
TUGBOAT CO.
PORTLAND
EAST
PORTLAND
MARINA
Hillsboro
Milwaukie
Oswego
Gladstone
West
Linn
SPORTCRAFT
34
WILLAMETTE
RIVER
Oregon
City
Newberg
Canby
275
50
SCALE IN MILES
0
5
10

FIGURE 8

Limited conclusions in regard to effects of siltation and turbidity upon growth and accumulation of slime may be drawn from the results. For instance, the decision to place the tiles in the boxes in a vertical position edgewise in the current was prompted by earlier experience with poor growth where tiles were laid flat in wire baskets. This was attributed to interference by silt and sand with the initial attachment by swarm cells of Sphaerotilus. Interference by abrasion has been previously referred to in connection with the tile box station #4 below Camas. Similar results of abrasion have been noted at Sportcraft on the Willamette where silt-laden flood waters have been observed to scour growth from the tile. The latter event was perhaps a consequence of increased turbulence and sheer power of current to dislodge growth already formed. Other evidence of adverse effects of turbulence has been noted above in reference to station 7 (Hassalo Rock) on the Columbia below Camas.

The correlation of chemical findings and current velocities with accumulation of growth on the tile is as satisfactory as can be expected under variable river conditions. The multiple factors and variables involved prevent a clear-cut correlation.

Nevertheless, the following conclusions may be drawn from the chemical data:

(1) The magnitude of the growth increases with an increase in carbohydrate concentrations in most cases. The carbohydrate test, however, must be further refined and applied more widely before completely satisfactory interpretation can be made.

(2) The test for sulfite waste liquor has value limited to close proximity to mill outfalls when waters are warm and perhaps at greater distances when waters are cold. However, this test is misleading when applied universally at all times of year and at distances removed from sources of wastes because it is a test for components that are slow to decompose by microorganisms whereas the principal growth promoting substances for slimes are rapidly utilized by the slimes and a host of other bacteria when water temperatures permit. This condition is illustrated on the Lower Willamette in summer where concentrations of sulfite waste liquor as measured by the test for lignins appear to persist with little diminution throughout the harbor to the Columbia, but at the same time production of Sphaerotilus decreases to almost nil. For this reason increase in growth does not always occur in proportion to the apparent sulfite liquor concentration. However, the results do show a distinct relationship between growth and the presence of liquor solids.

Bibliography

1. Lincoln, J. H. and Foster, R. F., "Report on Investigation of Pollution in the Lower Columbia River", for the Washington Pollution Control Commission and the Oregon State Sanitary Authority. 143 pp. - 1943.

2. Peterson, Donald R., "An Investigation of Pollution in the Lower Columbia River", for the Washington Pollution Control Commission, 1954.

3. Liebmann, Hans "The Action of Sulphite Cellulose Waste Liquors on Smaller and Larger Streams." Gesundh. Ing. 72 Nr. 17/18, 1951.

4. Washington Pollution Control Commission and the Crown Zellerbach Corporation, Camas "Columbia River Study" - A progress report, 59 pp. Illustrated, 1956-58.

5. Kühnl, G. "Investigation into the Physiology and Nutrition of Sphaerotilus natans" - Archiv. fur Mikrobiologie, 23,207, 1955.

6. Liebmann, Hans "Handbuch der Frischwasser Und Abwasserbiology" Munich, 1951.

7. "Standard Methods for the Examination of Water, Sewage and Industrial Wastes" 10th Edition, Amer. Public Health Assn., N.Y.N.Y. 1955.

8. Welch, P. S. "Limnological Methods" - The Blakiston Co.

9. Morris, D. L. "Quantitative Determination of Carbohydrates with Dreywoods Anthrone Reagent" - Science 107:254-255, 1948.

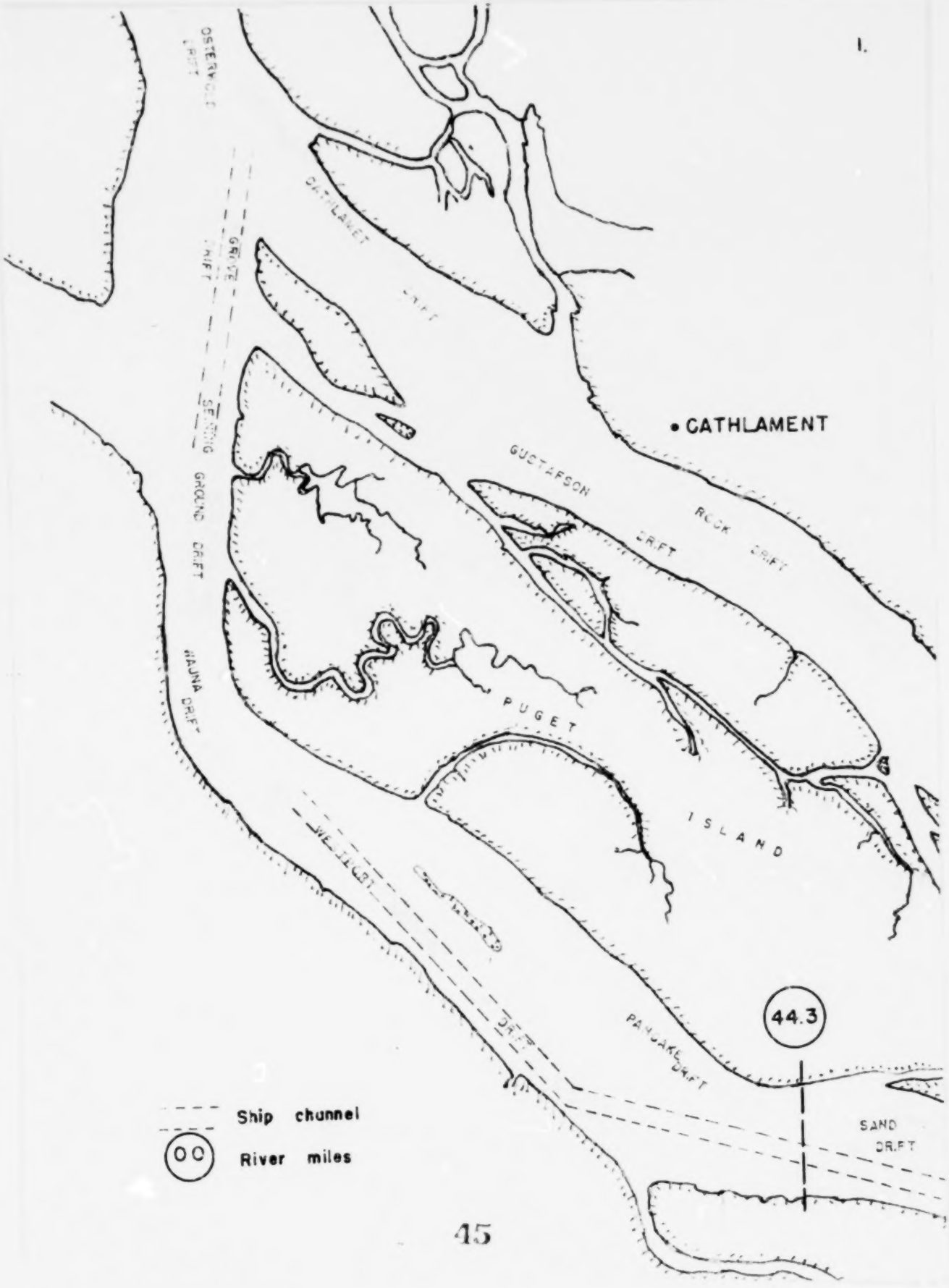
APPENDIX I

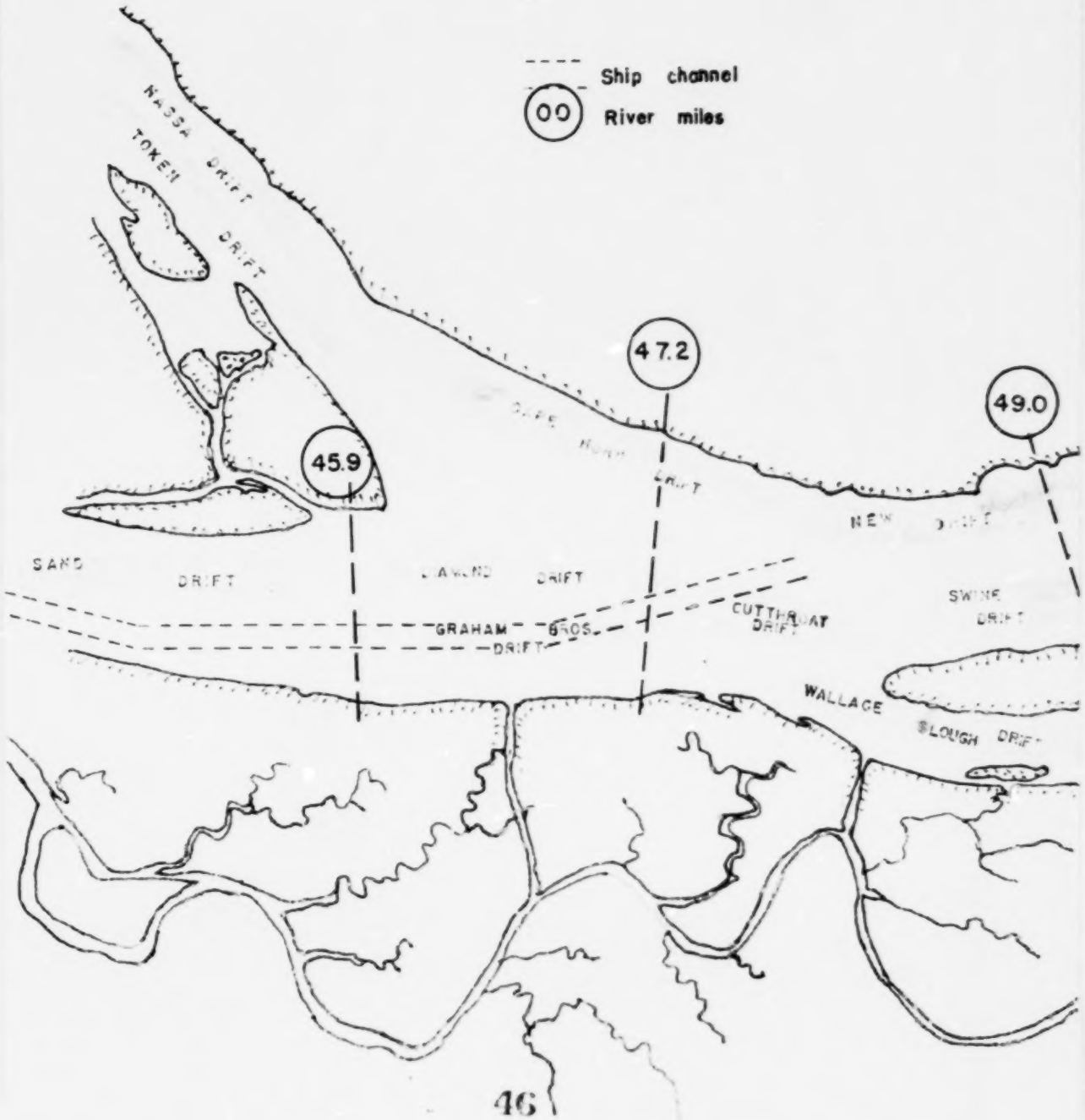
MAPS

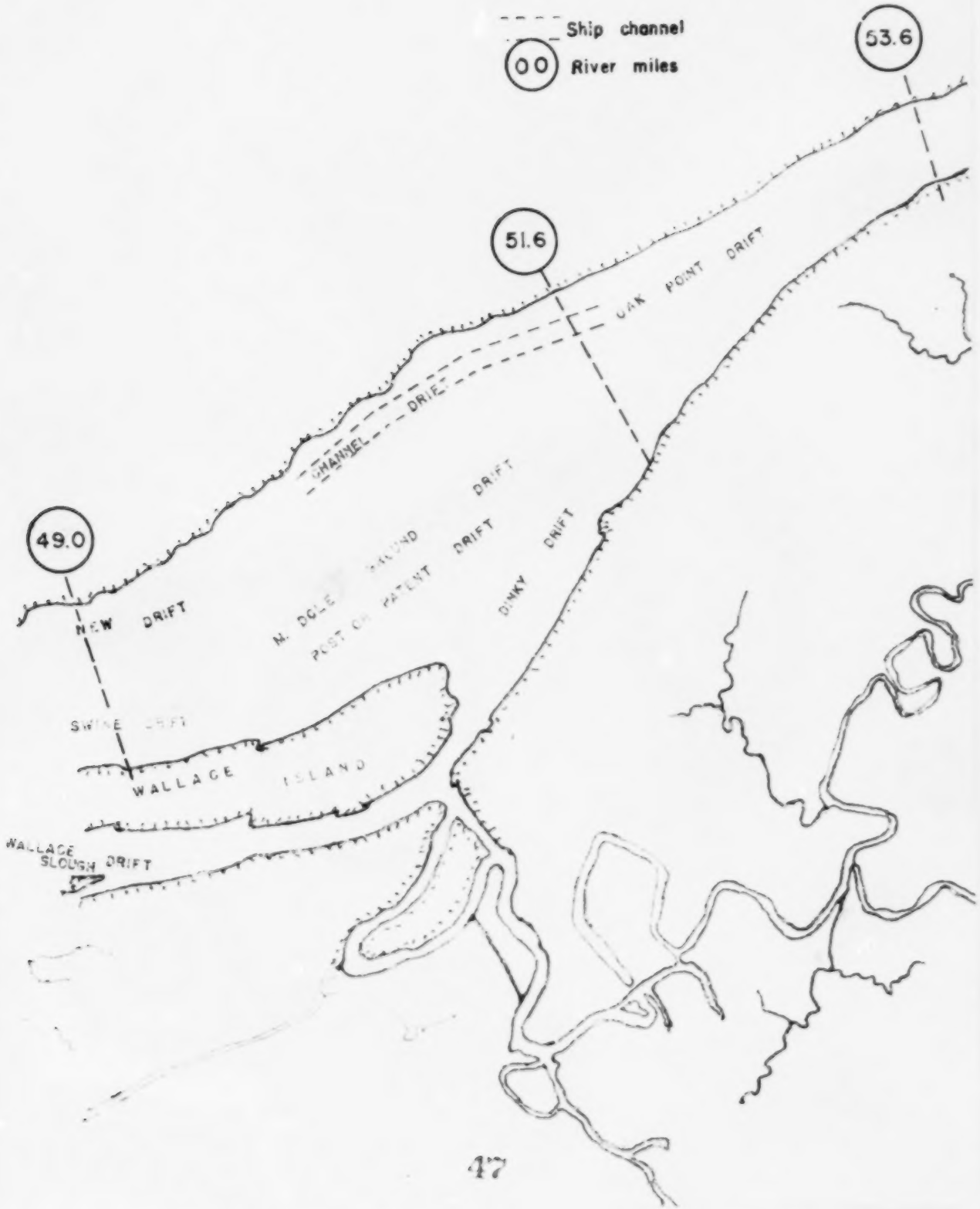
COLUMBIA RIVER MAPS

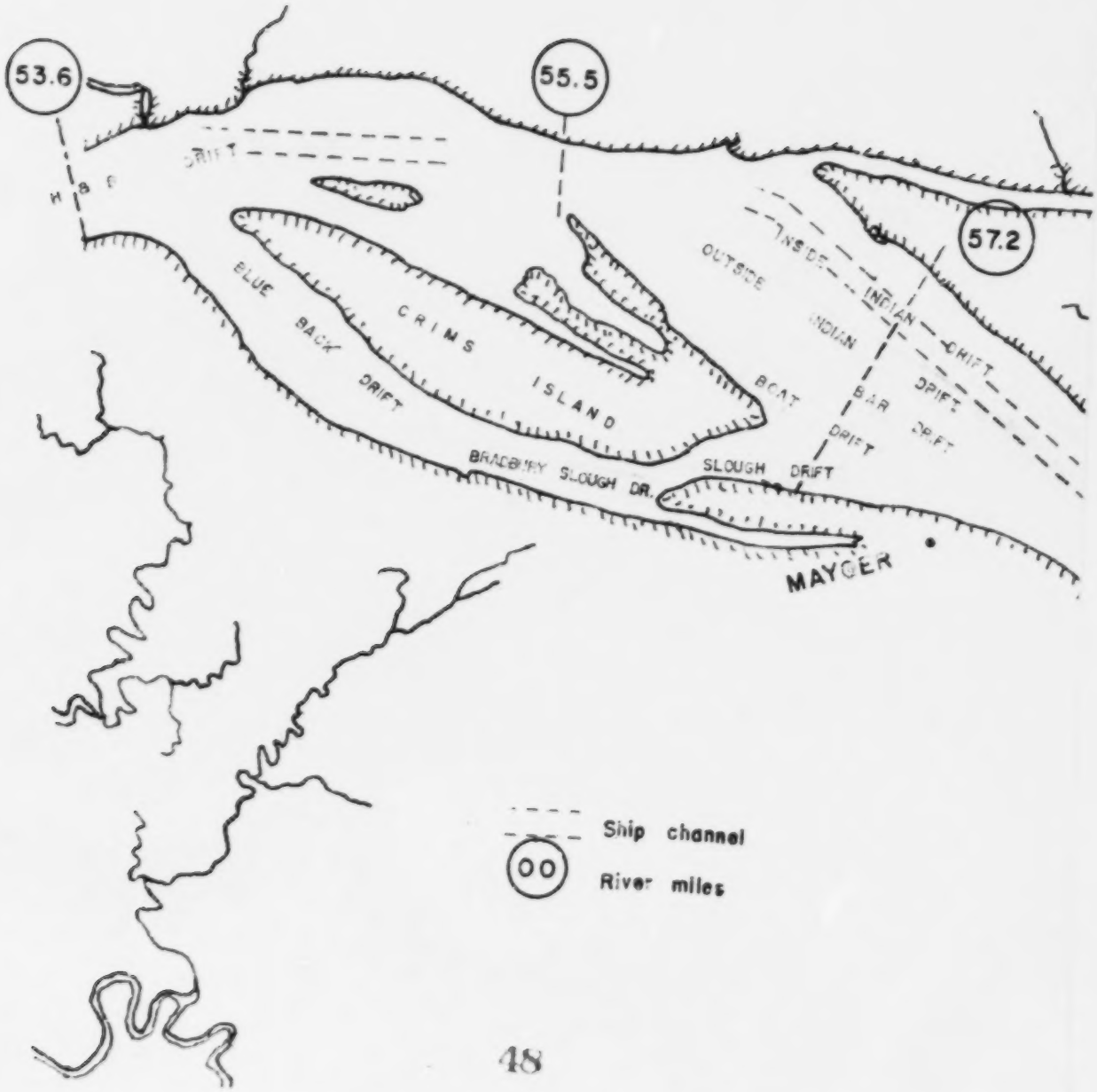
(Traced from U. S. Coast & Geodetic Survey Map)

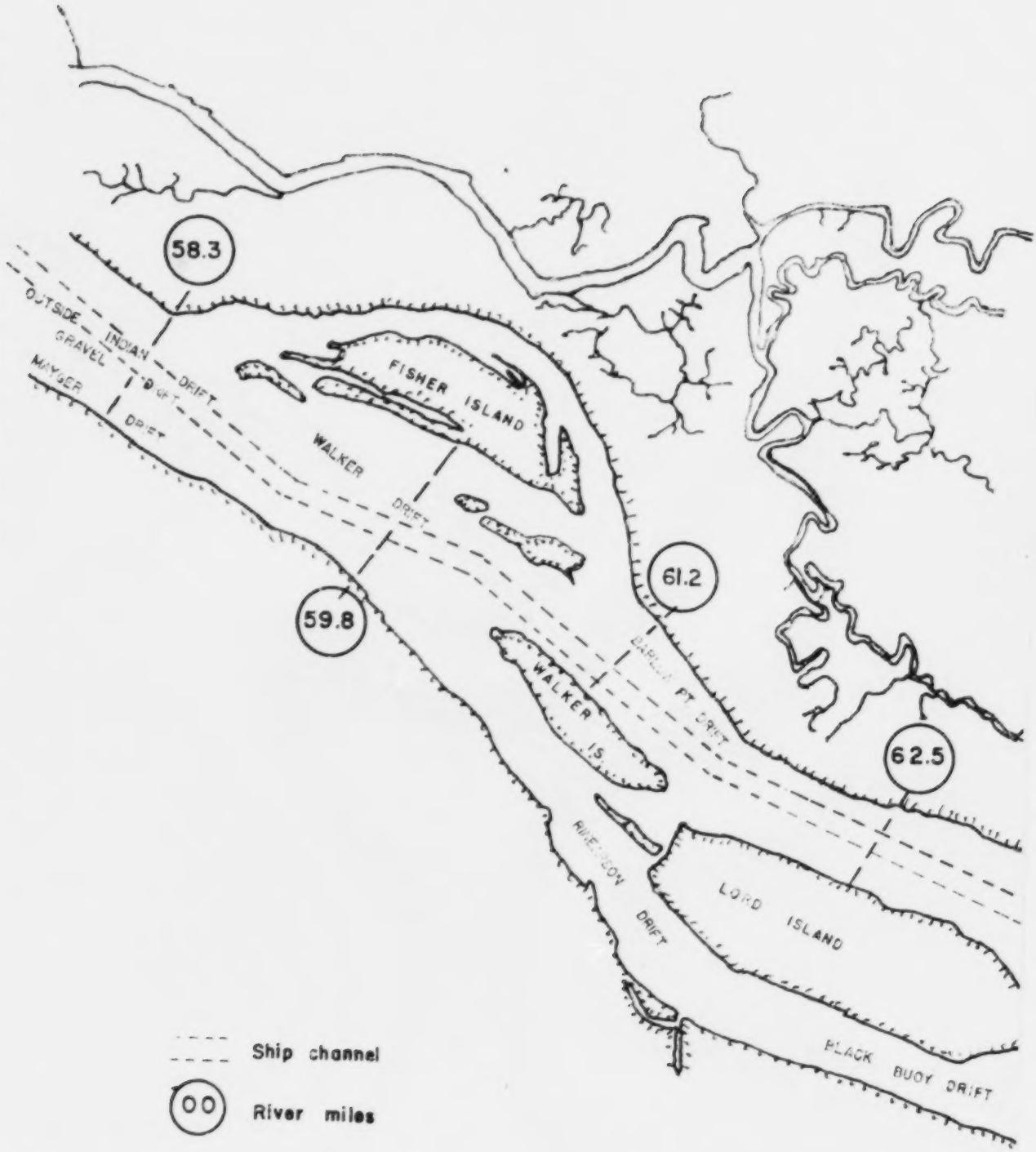
PAGE	RIVER MILES (approximate) from	to
1	38	44
2	44	49
3	49	54
4	54	58
5	58	63
6	63	68
7	68	74
8	74	82
9	82	89
10	89	96
11	96	102
12	102	108
13	108	112
14	112	117
15	117	122
16	122	128

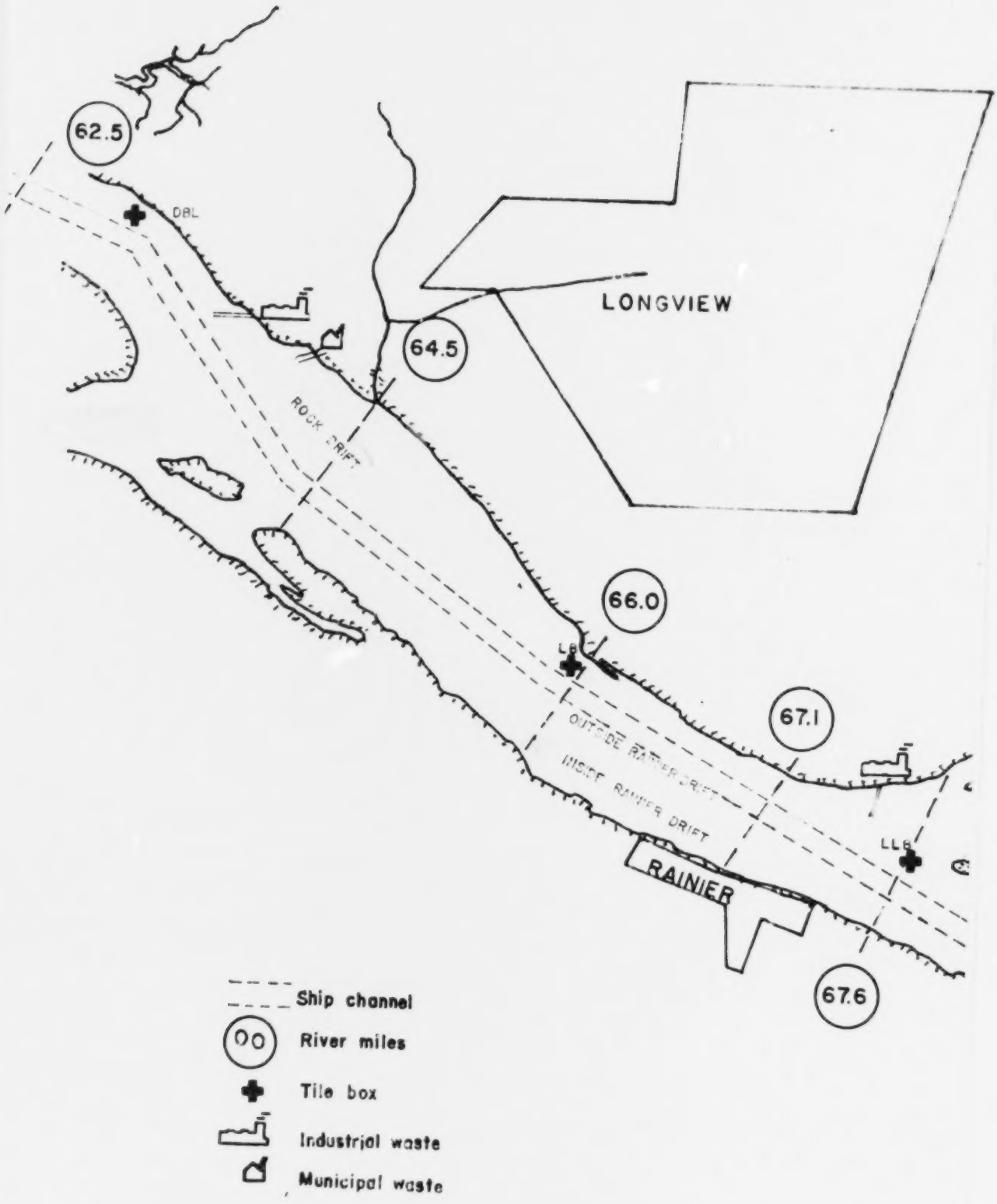

I.
OSTRANDER DRIFT
CATHLAMET DRIFT
SEEDING GROUND DRIFT
HUNA DRIFT
• CATHLAMENT
GUSTAFSON ROCK DRIFT
PUGET ISLAND
6
WESTPORT
DRIFT
PANCAKE DRIFT
44.3
SAND DRIFT
Ship channel
00 River miles

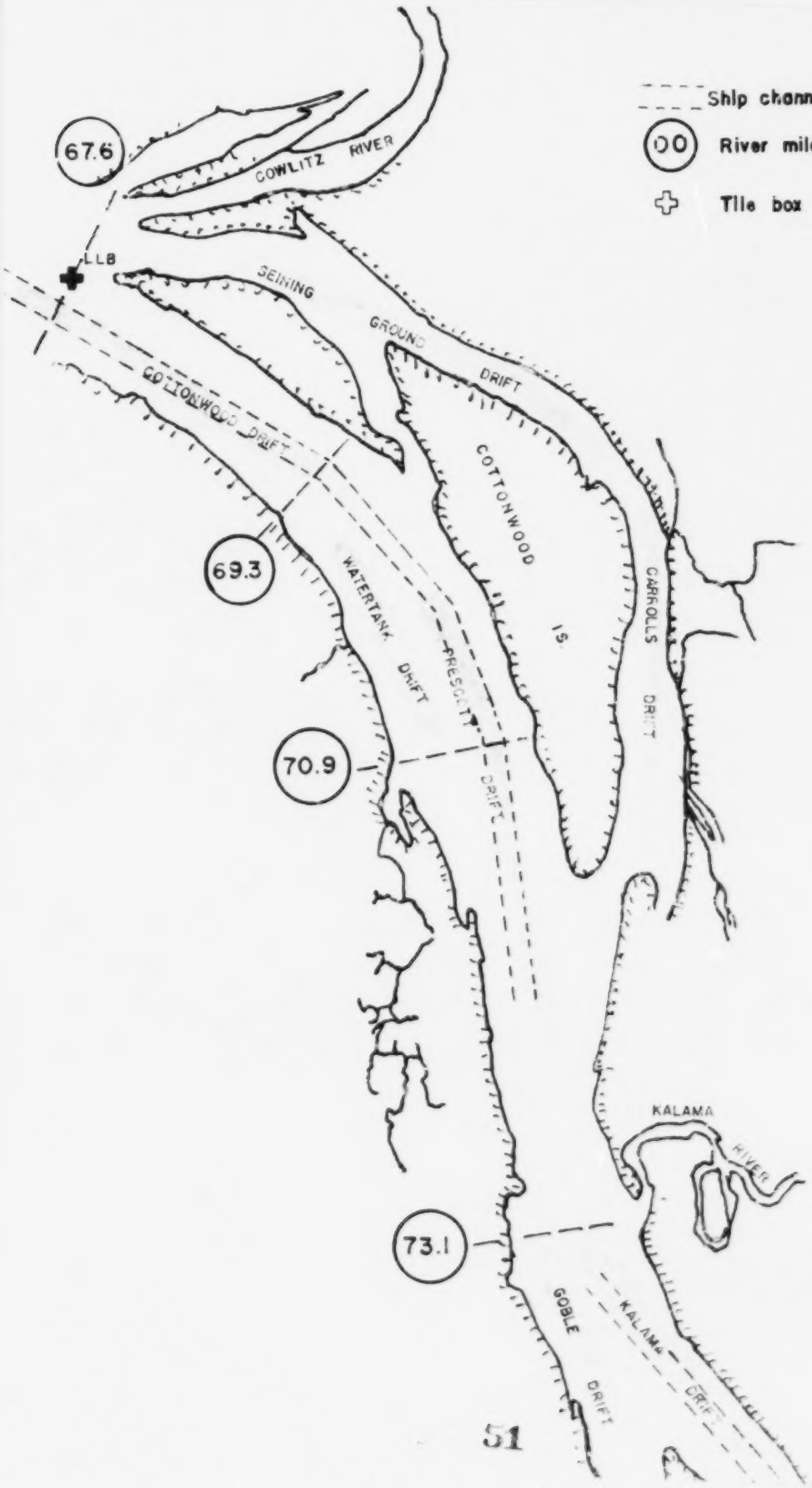

Ship channel
00 River miles
NASSA
TOKEN
DRIFT
DRIFT
47.2
49.0
45.9
SAND
DRIFT
DRIFT
GRAHAM
DRIFT
BROS.
CUTTHROAT
DRIFT
SWINE
DRIFT
WALLACE
SLOUGH

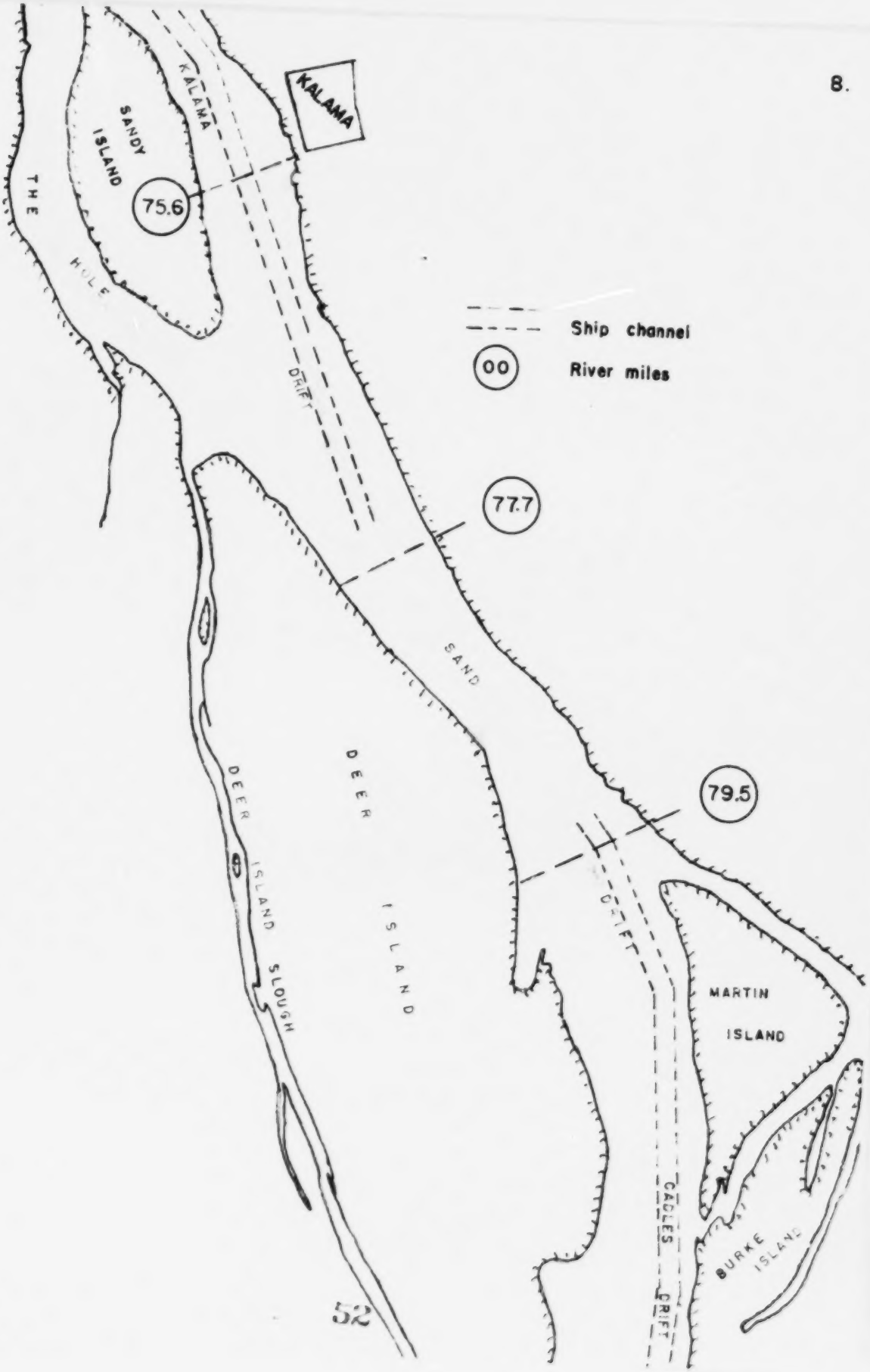

Ship channel
00 River miles
53.6
51.6
49.0
OAK POINT DRIFT
CHANNEL DRIFT
DRIFT
DRIFT
DRIFT
NEW DRIFT
WALLACE ISLAND
WALLACE SLOUGH DRIFT

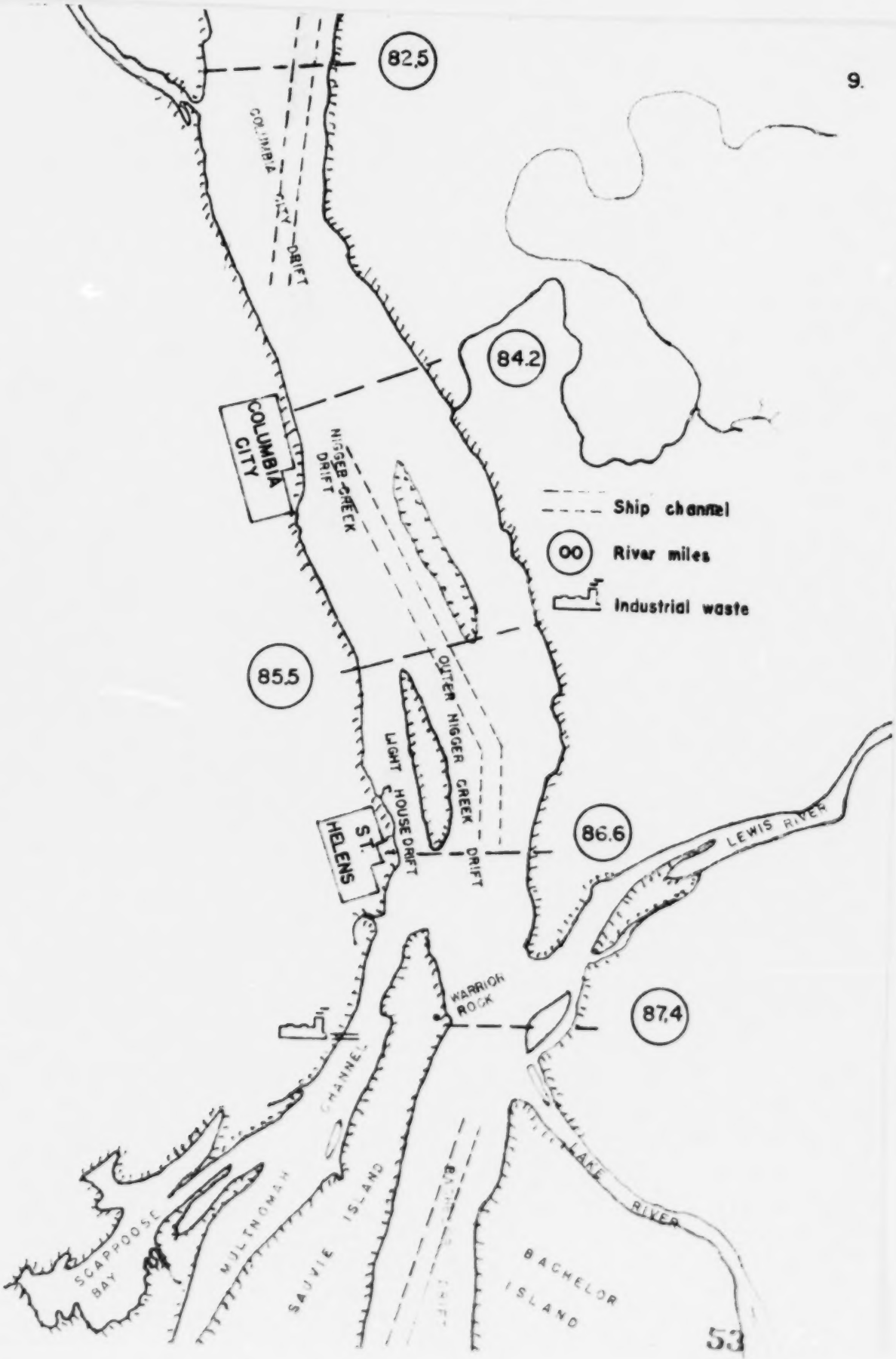

53.6
55.5
57.2
DRIFT
H & P
BLUE BACK DRIFT
CRIMS ISLAND
OUTSIDE INDIAN BAR DRIFT
INSIDE INDIAN DRIFT
BOAT DRIFT
SLOUGH DRIFT
BRADBURY SLOUGH DR.
MAYGER
Ship channel
00
River miles

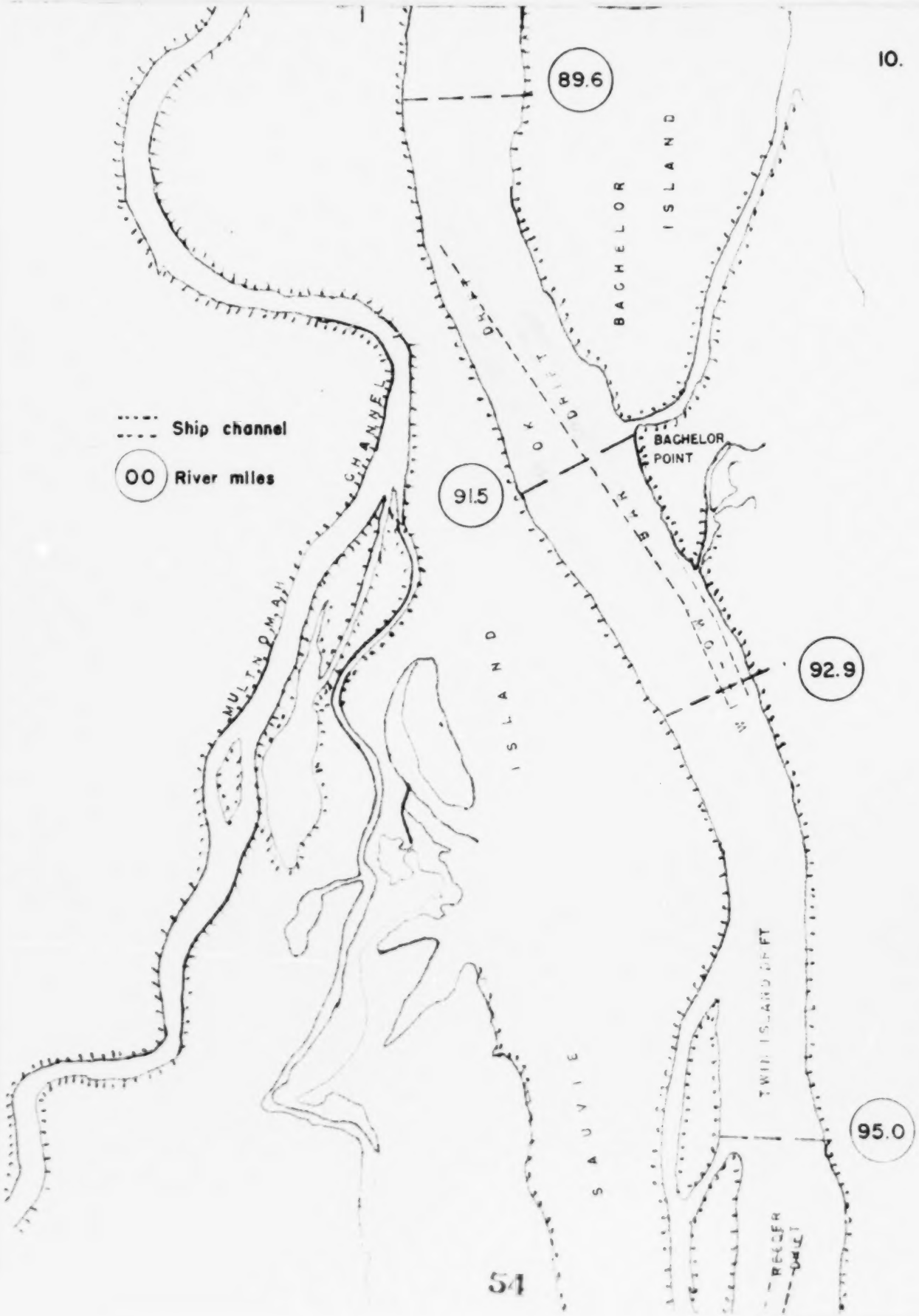

58.3
OUTSIDE GRAVEL BAR
INDIAN DRIFT
MAYGER DRIFT
FISHER ISLAND
WALKER DRIFT
59.8
61.2
BARGE PT. DRIFT
WALKER IS.
62.5
RIVERSIDE DRIFT
LORD ISLAND
BLACK BUOY DRIFT
Ship channel
00
River miles

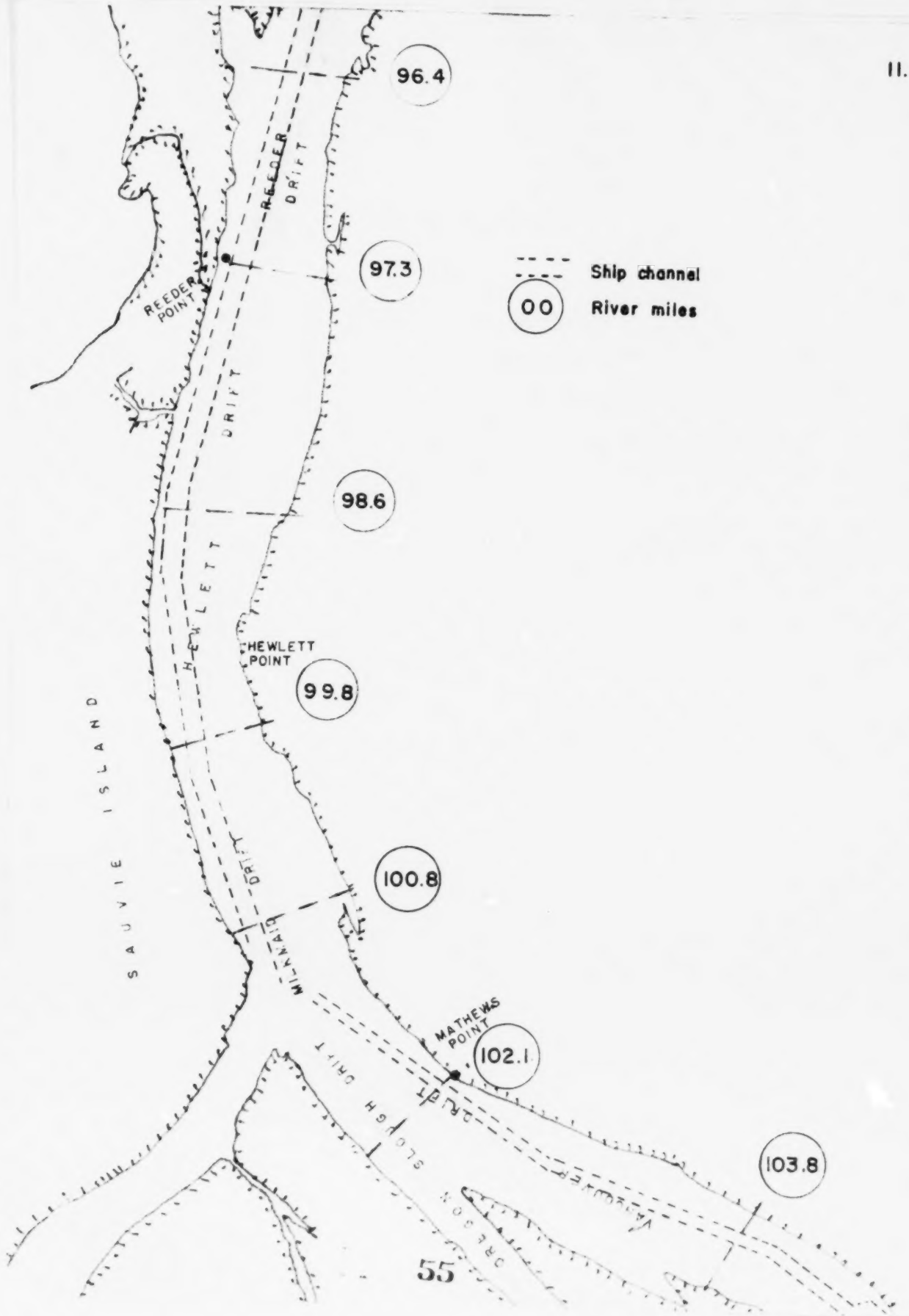

62.5
DBL
LONGVIEW
64.5
ROCK DRIFT
66.0
LB
67.1
OUTSIDE RAINIER DRIFT
INSIDE RAINIER DRIFT
LLB
RAINIER
67.6
Ship channel
00 River miles
Tile box
Industrial waste
Municipal waste

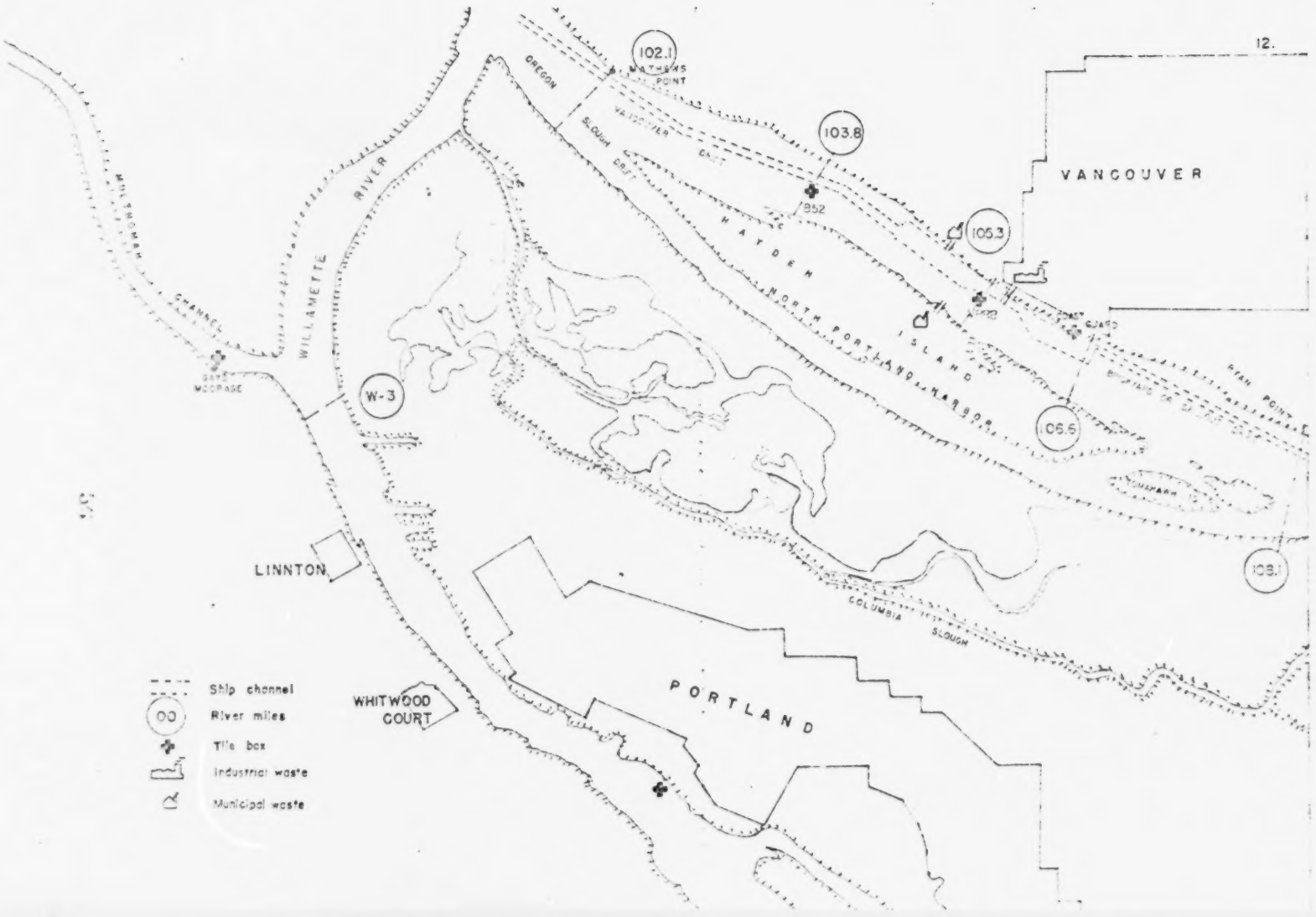

Ship channel
River miles
Tile box
67.6
COWLITZ RIVER
LLB
SEINING GROUND
DRIFT
COTTONWOOD DRIFT
69.3
WATERTANK DRIFT
COTTONWOOD IS.
CARROLLS DRIFT
PRESCOTT DRIFT
70.9
KALAMA RIVER
73.1
GOBLE DRIFT
KALAMA DRIFT

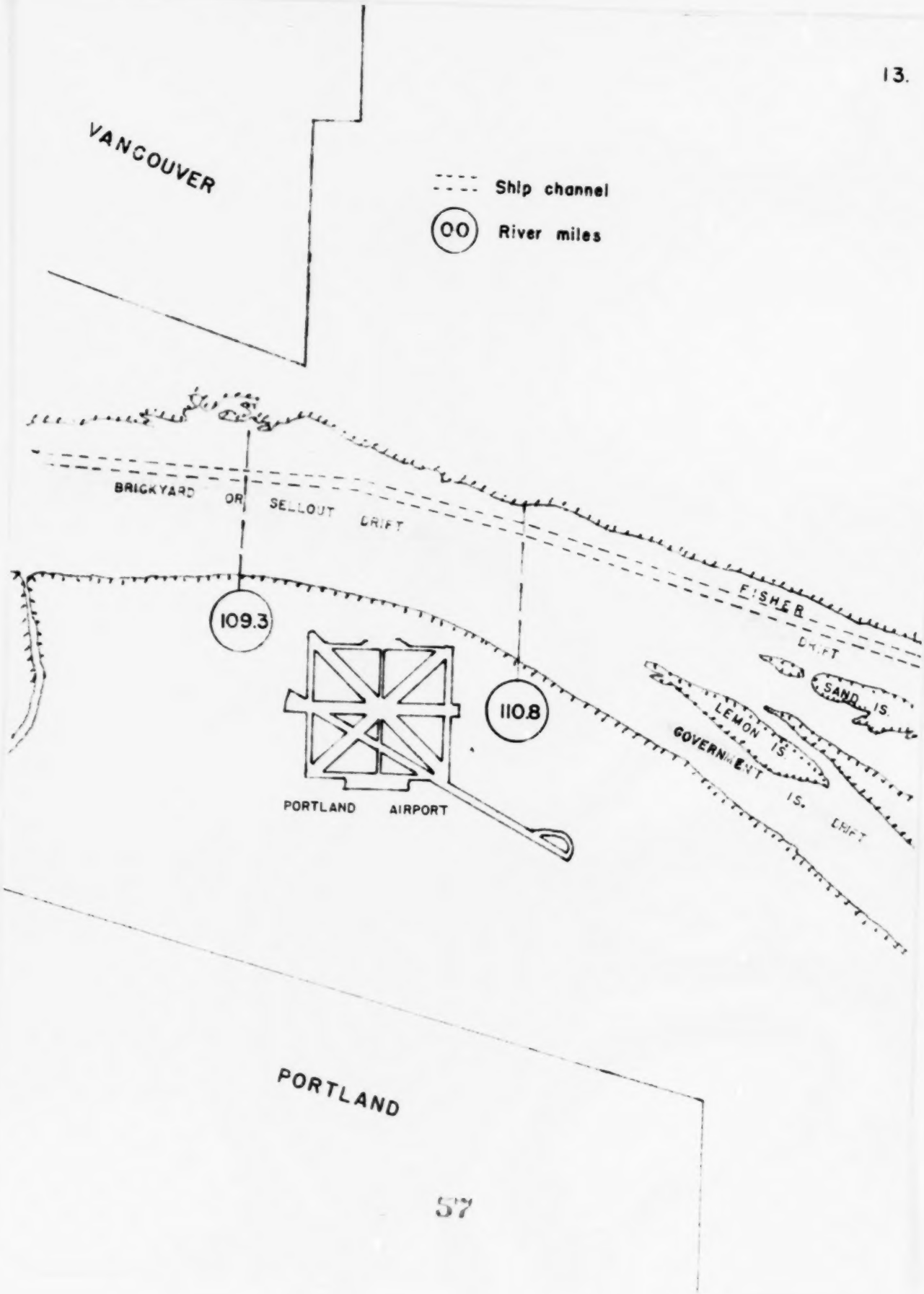

KALAMA
KALAMA
SANDY ISLAND
75.6
THE HULE
DRIFT
Ship channel
00
River miles
77.7
SAND
DEER ISLAND SLOUGH
DEER ISLAND
79.5
DRIFT
MARTIN ISLAND
CAGLES DRIFT
BURKE ISLAND

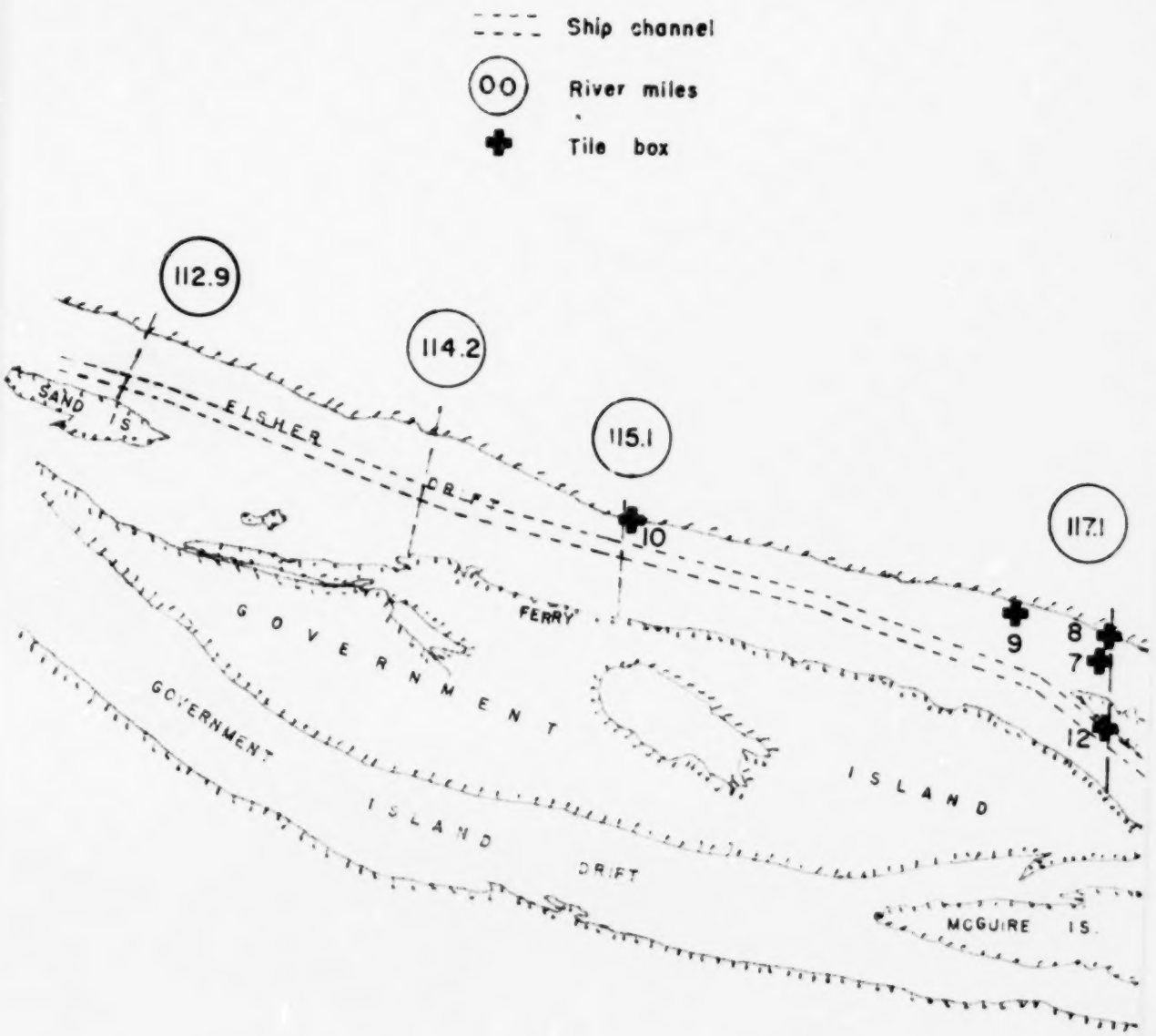

82.5
84.2
85.5
86.6
87.4
COLUMBIA CITY
ST. HELENS
NIGGER CREEK DRIFT
OUTER NIGGER CREEK DRIFT
LIGHT HOUSE DRIFT
WARRIOR ROCK
LEWIS RIVER
LAKE RIVER
SCAPPOOSE BAY
MULTNOMAH CHANNEL
SAUVIE ISLAND
BACHELOR ISLAND
Ship channel
River miles
Industrial waste

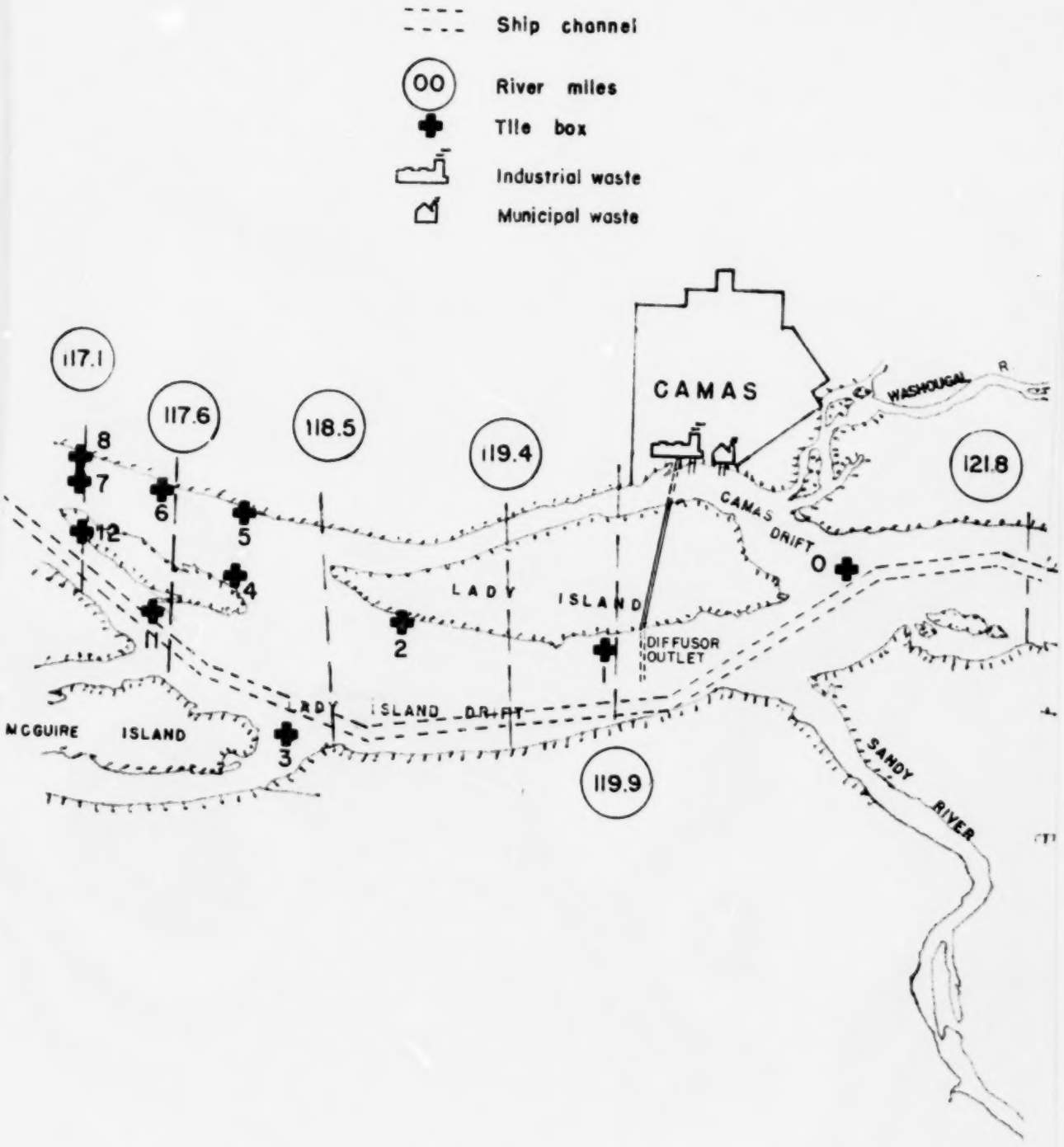

89.6
BACHELOR ISLAND
BACHELOR POINT
91.5
92.9
95.0
MULTNOMAH CHANNEL
SAUVIE ISLAND
Ship channel
00 River miles

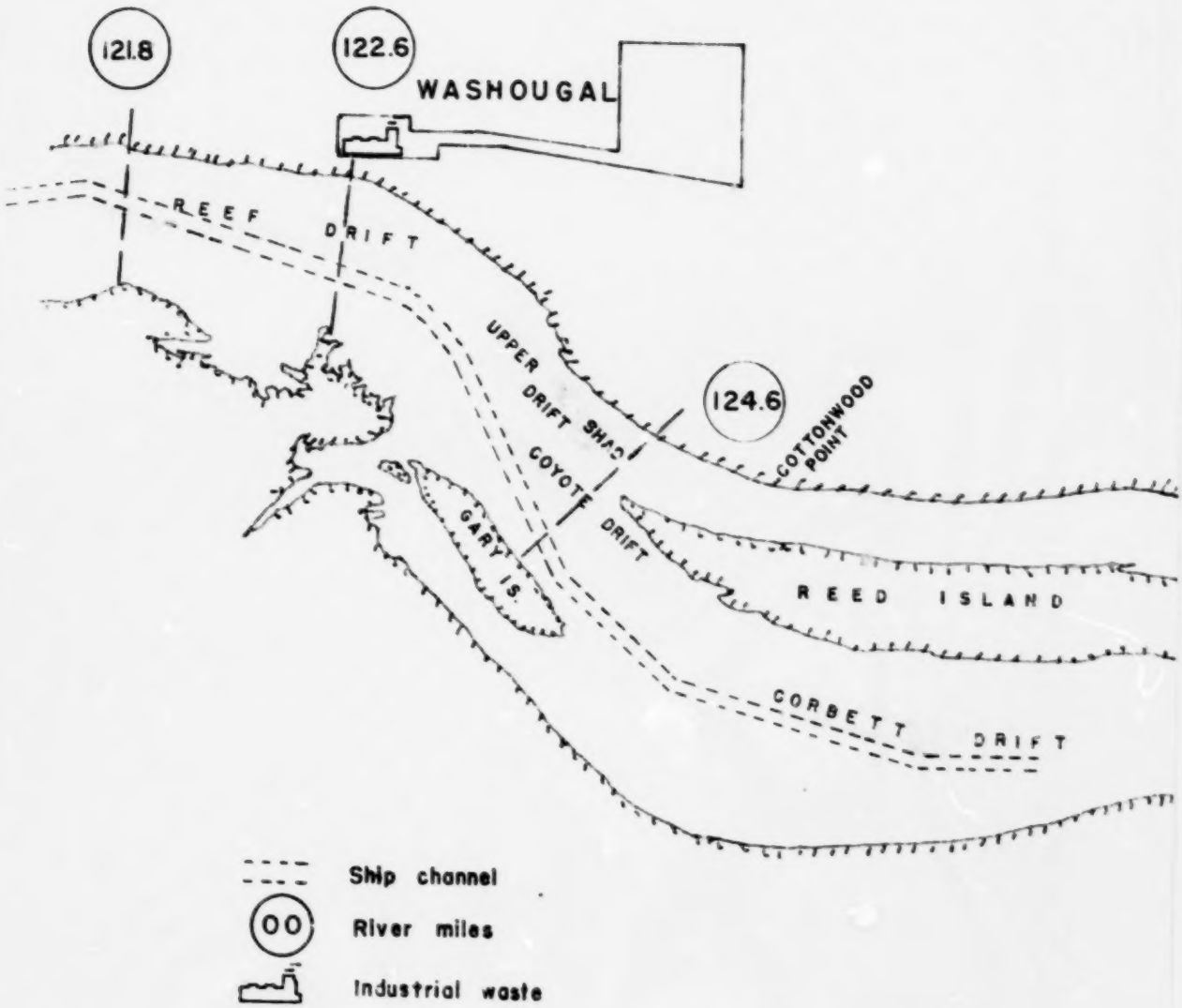

96.4
97.3
98.6
99.8
100.8
102.1
103.8
REEDER DRIFT
REEDER POINT
HEWLETT DRIFT
HEWLETT POINT
SAUVIE ISLAND
MIDWAY DRIFT
MATHEWS POINT
SLOUGH DRIFT
Ship channel
River miles
00


102.1
MATHEWS POINT
103.8
105.3
106.5
108.1
W-3
OREGON
SLOUGH
VANCOUVER
DRIFT
1952
HAYDEN
ISLAND
NORTH PORTLAND HARBOR
VANCOUVER
WILLAMETTE
RIVER
MULTNOMAH
CHANNEL
GAS
MOORAGE
LINNTON
COLUMBIA
SLOUGH
PORTLAND
WHITWOOD
COURT
RYAN POINT
Ship channel
River miles
Tile box
Industrial waste
Municipal waste


VANCOUVER
Ship channel
00 River miles
BRICKYARD OR SELLOUT DRIFT
FISHER DRIFT
109.3
110.8
SAND IS.
LEMON IS.
GOVERNMENT IS.
DRIFT
PORTLAND AIRPORT
PORTLAND


Ship channel
00 River miles
Tile box
112.9
114.2
115.1
117.1
SAND IS.
ELSHER
10
9
8
7
12
FERRY
GOVERNMENT
ISLAND
GOVERNMENT
ISLAND
DRIFT
MCGUIRE IS.


Ship channel
00 River miles
Tile box
Industrial waste
Municipal waste
117.1
117.6
118.5
119.4
119.9
121.8
CAMAS
WASHOUGAL R.
CAMAS DRIFT
LADY ISLAND
DIFFUSOR OUTLET
LADY ISLAND DRIFT
MCGUIRE ISLAND
SANDY RIVER
1
2
3
4
5
6
7
8
11
12
O


121.8
122.6
WASHOUGAL
REEF
DRIFT
UPPER DRIFT SHAL
124.6
COTTONWOOD POINT
COYOTE
DRIFT
GART IS.
REED ISLAND
CORBETT
DRIFT
Ship channel
00
River miles
Industrial waste

APPENDIX II

DESCRIPTION OF

SAMPLING POINTS

SAMPLING STATIONS ON COLUMBIA RIVER

WASHOUGAL TO PUGET SOUND

Tile Box Station	Code Stream Mile	Description
Camas - Washougal		
	124.6	Above Washougal - Coast Guard Light #54-Gary Island
	122.6	Opposite Washougal - Coast Guard Light #50
	121.8	Port of Camas - Washougal
0	120.3	Tile Box (T.B.) location at upper northeast edge of rock crib which protects base of power line tower
	120	Diffusor outlet line, Crown Zellerbach Co., Camas, Wn.
	119.9	First cross section downstream from diffusor
1	119.6	T. B. location 100 feet out from rock point, Lady Island
	119.4	Second cross section below diffusor
2	118.9	T. B. location at tenth dolphin west of diffusor along southwest shore of Lady Island
	118.5	Cross section at downstream end of Lady Island
3	118.2	T. B. location at Coast Guard Light #36. Oregon side of ship channel

Tile Box Station	Code Stream Mile	Description
Camas - Washougal - continued		
4	117.9	T. B. location at most easterly dolphin (upstream) on the island side of "Hassalo" channel and below lower end of Camas slough
5	117.9	T. B. location fifty feet out from Washington shore at dolphin near boathouse
	117.6	Cross section one-half mile upstream from Hassalo Rock
6	117.5	T. B. location fifty feet out from Washington shore at dolphin and on shoreward side of log rafts
11	117.5	T. B. location island side of main ship channel and 150 feet out from island during low flow
7	117.1	T. B. location, Hassalo Rock, tied to Coast Guard Buoy
8	117.1	T. B. location Coast Guard "F" Ref., near Washington shore
12	117.1	T. B. location island side of main ship channel. This is known as "Hassalo Section"
9	116.5	T. B. location Coast Guard "F" Ref., Rock Quarry, near Washington shore

Tile Box Station	Code Stream Mile	Description
Camas - Washougal - continued		
10	115.1	T. B. location Coast Guard "29" light near Washington shore at ferry to Government Island
	114.2	Coast Guard Light #27
	112.9	Coast Guard Light #23 opposite Sand Island
Portland - Vancouver		
	110.8	Coast Guard (C.G.) Light #19, Lelser Point
	109.3	C. G. Light #13
	108.1	Ryan Point, above Vancouver
Coast Guard	106.5	T. B. location upstream side of dock at Coast Guard station, near Wash. shore
	106.5	Interstate Highway #99 Bridge, near upper end of Hayden Island
VRRB	105.3	T. B. location lower end of drawbridge, Spokane, Portland and Seattle Railroad Bridge. Cross section immediately above this bridge. Downstream from waste diffusor of Columbia River Paper Mill
B 52	103.8	T. B. location Buoy "52" C.G. Oregon side of main ship channel and immediately upstream from power line crossing

Tile Box Station	Code Stream Mile	Description
Portland - Vancouver - continued		
	102.1	Matthews Point - C.G. Light #45 - lower end of Hayden Island and above mouth of Willamette River
	100.8	C. G. Light #34 immediately downstream from Willamette River Mouth
	99.8	C. G. Light #36
	98.6	C. G. Light #32
	97.3	C. G. Light #28 - Reeder Point
	96.4	C. G. Light #26
	95.0	C. G. Light #21
	92.9	C. G. Light #17
	91.5	C. G. Light #13 - Bachelor Point
	89.6	C. G. Buoy #7 - Middle Bachelor Island
St. Helens		
	87.4	Warrior Rock - above St. Helens and upstream from Mouth of Multnomah Channel
	86.6	C. G. Light #5 - off St. Helens waterfront
	84.2	C. G. Light #76 - Columbia City

Tile Box Station	Code Stream Mile	Description
St. Helens - continued		
	82.5	C. G. Light #73
	81.0	C. G. Light #67 - upper end of Martin Island
	79.5	C. G. Light #62 - Martin Bluff
	77.7	C. G. Light #57
	75.6	C. G. Light #47 - Kalama
	73.1	C. G. Light #42 - Coffin Rock
	70.9	C. G. Light #41 - near upper end of Cottonwood Island
	69.3	C. G. Light #31 - near lower end of Carroll Channel
Longview		
LLB	67.6	T. B. location - C. G. Buoy #29. Immediately northeast of ship channel and upstream from Mouth of Cowlitz River
	67.1	Below Mouth of Cowlitz and Town of Rainier, Oregon
LB	66	T. B. location - Interstate Highway Bridge. Sampler tied to dolphin near Wash. side and 200 feet downstream from bridge
	64.5	C. G. Buoy #23 - immediately upstream from outfall of Weyerhaeuser Mgo mill

Tile Box Station	Code Stream Mile	Description
Longview - continued		
DBL	63	T. B. location - triple piling (dolphin) at end of plank jetty which is 1500 feet upstream from lower slaughters range
	62.5	C. G. Buoy #15 - powerline crossing below slaughters range
	62	C. G. Light #12 - Walker Island
	59.8	C. G. Light #7 - Fisher Island
	58.3	C. G. Buoy #2 - lower end of Fisher Island Slough and above Mayger, Oregon
	57.2	C. G. Light #3 - below Mayger-upper end of Bradbury Slough and Crims Island
	55.5	C. G. Light #85 - Bunker Hill
	53.6	C. G. Light #81 - Oak Point
	51.6	C. G. Buoy #79-lights 80 & 2
	49.0	C. G. Light #69-Waterford, Wn.
	47.2	C. G. Buoy #68
	45.2	C. G. Light #64 - upper end Puget Island
	44.3	C. G. Light #60 - Pancake Point on Puget Island

APPENDIX III

FIELD EQUIPMENT AND METHODS

Methods for Bottom Sampling

The usual methods for sampling deep rivers as described in "Standard Methods for the Examination of Water, Sewage and Industrial Wastes" 10th Ed. (7) were tried in the early stages of the project - Fall, 1955. These included Ekman and Petersen dredges and a heavy "mud snapper" of the type used in marine work. The Petersen dredge was used with some success, but this device had three principle shortcomings in the determination of slime occurrence: (1) tendency to disperse slime on the bottom when dropped or closed too rapidly; (2) heavy handling slowed reconnaissance procedure and produced more bottom material than was necessary; and (3) failure to close or to collect a sample on hard bottom or in heavy gravel.

The Oregon Fish Commission has for some years been using a small steel trawling device to determine distribution of smelt spawn in deep river gravels. This trawl measures 12 inches wide, 5 inches high and 20 inches long, and has sharpened edges around the open end. When the device is lying on the bottom in position to be dragged, it has metal panels on top and bottom and bronze wire screen (20 mesh) on sides and after-end.

Owing to its light weight (about ½ that of Petersen dredge) and ease of handling in the field, the bottom trawl was adopted for use throughout the remainder of the project.

The procedure was to throw the device out as far as possible from the boat and play the rope out to allow quick descent to the bottom, whereupon, with boat in motion, trawling over an estimated 3 - 6 feet of bottom was accomplished before retrieving. By this means, a minimum of sand was caught but slimes settled on or growing from bottom surfaces would be dislodged and brought up in the trawl. After visual observation and cleansing by grasping the safety rope attached to the posterior end of the trawl, the sampler was ready for the next test on the stream section.

The following numbers and letters are used to designate the amount and character of the growth observed in the bottom samples taken:

Letter A - Designates living growth typified by the whitish glow at the extremes of the growth and the slick, slimy feel to the fingers.

Letter D - Designates dead growth, which does not have the gray-white "end" growth. The growth has a slimy texture but is usually associated with silt and sand.

Number 1 - Shows growth of very minor significance. An example being a single strand of alive growth (1A) hung on the side of the bottom sampler screen just large enough for

visual identification. Dead growth amounting to about 5 ml. rolled up on top of the sand in the sampler would be classified as 1D.

Number 2 - Growth in the amount of about 10 ml. Possibly 3 or 4 strands of "A" growth or several balls of "D" growth.

Number 3 - Growth between 10 ml. and 1 liter.

Number 4 - Designates a quantity of growth in excess of 1 liter. This classification may be found most generally in deep pockets of the river and in quantity may cover the bottom of the sampler to a depth of several inches.

The letter N indicates that no growth was observed.

The Tile Box Sampler

The tile box sampler consisted of a box 6 inches high, 30 inches long and 8 inches deep, open on the sides and made of ½-inch plywood. Six pairs of quarter-round cleats were placed at the bottom and top of the box to hold the tile in a vertical position parallel to the ends of the box. Two plywood fins, 8 by 36 inches were tacked to the sides of the box to adjust it into the current. Weights of about 20 pounds were attached to the bottom for ballast.

The tile was six inches square and 3/8 inch thick with one unglazed side and one ribbed side. A smaller sampler employing four-inch tiles was also developed. A drawing of this model is included.

The boxes were equipped with buoys to mark their location. These buoys consisted of 25-gallon barrels painted yellow with a white stripe. These were rigged with treated ½-inch rope with snaps at the surface end and were anchored with concrete blocks weighing from 75 to 100 pounds. The boxes were placed at approximately half depth in the stream. To help prevent loss of samplers, treated ropes were replaced by chain, 1200 lb. test.

After the box was anchored in position for a desired period it was lifted into the boat, the tile removed and number noted. The growth was removed from the smooth surface of the tile into a ½-pint jar using a rubber scraper, a jar funnel and river water from a plastic squeeze bottle. Growth caught on the leading edge of the tile and any other extraneous growth washed onto the tile by the current was not included with the sample. The jar was not filled more than necessary with wash water. The sample was preserved by adding 3 ml. of 86 percent formaldehyde solution.

After the samples had been taken the tile was scrubbed on both sides with scouring powder and a vegetable brush. After rinsing it was placed in a strong chlorine solution for one minute and replaced in the sample box.

1. Wherever possible, it is desirable to fasten the samplers to fixed piling or similar objects.

2. Where necessary to use buoys and anchors, the latter should weigh at least one hundred pounds and the former should be weighted sufficiently to provide some stability in the water.

3. The tile boxes should be suspended at mid-depth or even one-third distance from the surface where shifting sand is a factor in the environment.

4. A sign showing U. S. Government ownership more plainly than heretofore should be used.

5. The tile box samplers provide the best means known to the investigators for determining rate and quantity of growth formation at a given location in contradistinction merely to straining growth from water passing a given point - growth that may have originated to a large extent from an upstream source.

Reighard Tow Net

To estimate the quantity of suspended slime passing a given point in the river, a Reighard tow net was constructed as described by Welch (8)*. This device is constructed similarly to a conical plankton tow but with the added feature of a framework of four steel rods bent in such a way to protect the bag and to act as runners to allow the net to be used as a bottom drag if desired.

The area of the net opening is one square foot and the silk bolting cloth is #16 mesh. Mesh size is an important consideration as too fine mesh in a swift stream clogs quickly with heavy silt particles and debris, but too coarse mesh would allow much of the more finely divided slimes and wood fibers to escape.

As indicated above the Reighart net may be used as a bottom drag to strain materials in suspension at depths within one foot to eighteen inches above the bottom. However, in order to estimate quantities of suspended slime passing a given point in a stream as reported in the studies on the Lower Willamette River of 1957, the boat was anchored where the current was strong enough to hold the net in a horizontal position at about mid-depth. Current velocity was estimated by means of timing a float in passage by the length of the boat (Current meter better - Clark-Bumpus tow net, still better).

Duration of the tow was five to seven minutes after which the entire contents of the net were washed into a sample bottle and preserved in 3 percent formalin. Volume of water passing through the net was estimated.

In the laboratory, the quantity of the total slime and debris was determined by one hour's sedimentation in an Imhoff cone. Microscopic examination and percent differentiation by volume was made just as was done with the samples from the tile boxes.

*"Limnological Methods" P. S. Welch, Blakiston Co. p. 310

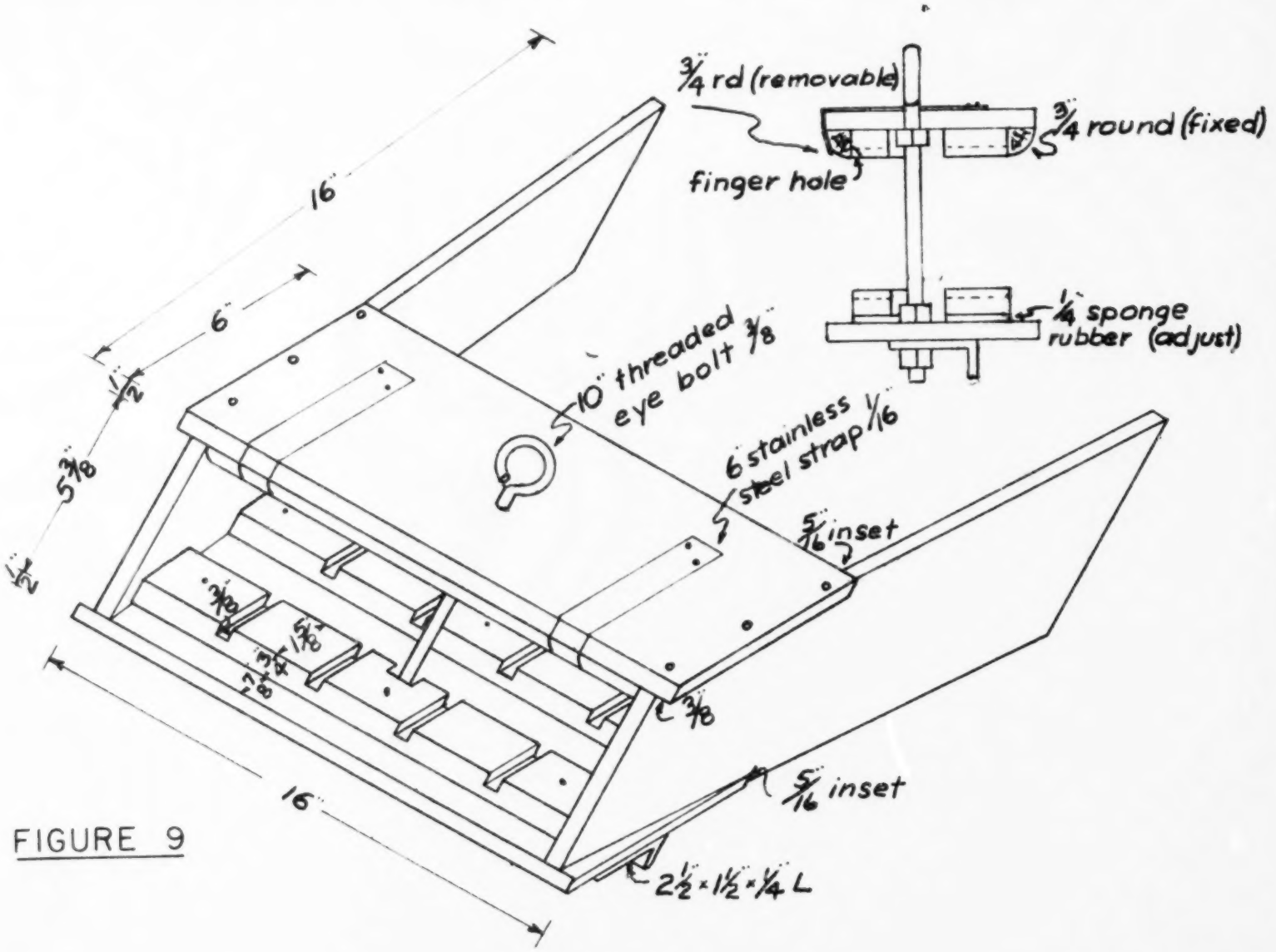


FIGURE 9

TILE BOX SAMPLER – 4" Model

APPENDIX IV

LABORATORY METHODS

Laboratory Methods for the Tile Box Tests

The following procedure was used as a quantitative test for the growth taken from the smooth surface of the tiles:

1. Shake sample jar to loosen settle solids.

2. Divide the sample into two calibrated 50 ml. centrifuge tubes.

3. Spin solids down in small centrifuge for 5 minutes at 1800 r.p.m. Pour off 2/3 of the supernatant, stir both tubes, and combine the heretofore divided sample into one 50 ml. calibrated centrifuge tube.

4. Spin combined sample in large centrifuge for 10 minutes at 2300 r.p.m.

5. Record total ml. of centrifuged solids and the ml. of light and dark stratum.

6. Pour off 3/4 of the supernatant from the centrifuged sample. Mix the contents thoroughly and add to total to a 35 ml. tared evaporating dish.

7. Evaporate to dryness (1 hour) and place in 103°C oven for one hour. Place sample in desiccator and cool, weigh and record weight. This gives the weight of total solids.

8. Place the evaporating dish in the muffle furnace at 600°C for 1½ hours. Place in desiccator to cool. Reweigh dish and record results. This is the weight of the fixed solids. The volatile solids is the difference between total and fixed solids.

The slime growth taken from the ribbed surface of the tile was examined under the microscope in the living condition. When this was not practicable, a concentrated formaldehyde or 70% alcohol was used to preserve the sample. (The former should be used in an amount sufficient to result in 3-5% mixture in the sample. The 70% alcohol should be added at the rate of about one ml. alcohol to 10 ml. of sample).

A drop of the material was placed on a slide, covered with a cover slip and examined under low and high power. The oil immersion objective was seldom required, but where necessary the use of the hanging drop technique is indicated.

Results are expressed qualitatively with relative abundance of the organisms given. Insofar as possible Sphaerotilus spp. is differentiated

from sulphur bacteria and from Zoogloea sp., the slime bacteria. The proportion of these two organisms is expressed as percent by volume. For example, the mass of growth may consist of 70% Sphaerotilus and 30% Zoogloea. Other organisms such as algae and protozoa are identified and recorded. Presence of large amounts of silt and other amorphous matter is also noted.

Determination of Sugar (Carbohydrate)

Because of the significance of sugars as components of nutrition for Sphaerotilus and certain related slimes, it was desired to undertake a test for their determination in the Columbia River at tile box locations where composite samples were obtained. Early in the study, the test (9) showed little promise. However, during fall and spring of 1955 and 1956, both Mr. Shadix of the Taft Center and Mr. Toombs of Oregon State Sanitary Authority continued to experiment with the test and necessary improvements which made it possible to place reliance on the subsequent tests.

APPENDIX V

TABLES

TABLE 1

TILE BOX RESULTS

INTERIM PERIOD - 1955-56

BETWEEN MILE 109 AND 124.6

Station Tile Box	Mile	Date Sampled 1955-56	Temp. H20 °C	Growth per square foot in Milligrams per week of exposure: Total Solids	Volatile Solids	Estimated Sphaerotilus & Assoc. Slime Organisms*
	124.6	10-26	14	40.7	4.6	Not determined
1	119.6	10-26	14	760	59.0	" "
7	117.1	10-26	14	1220	116	" "
	109.3	10-26	14	350	126	" "
	124.6	11-2	11	94	13	12.4
1	119.6	11-2	11	2151	242.8	230.7
7	117.1	11-2	11	1469	286.4	272.1
	109.3	11-2	11	1782	594	569
3	118.2	11-2	11	116	21	30
	124.6	11-9	9	35.6	12.8	12.4
1	119.6	11-9	9	346	84	79.8
	109.2	11-9	9	242.6	113	113
3	118.2	11-9	9	48.4	15.4	15.4
	109.3	11-17	4.5	330	41.6	----
1	119.6	12-20	2	1532	13.5	13.5
3	118.2	12-20	2	241.4	19.5	1
1	119.6	12-27	2	556	30.6	29.07
3	118.2	12-27	2	42.8	10.6	10.1
	124.6	1-10	3	18	5.55	
1	119.6	1-10	3	779.1	66.1	
	118.5	1-10	3	100	7.6	

* Corrected by arbitrary subtraction of 5 percent where plankton and other drifting organisms occur entrapped in slime.

TABLE 2

FLOW RECORD-1956

Date March	Flow at Celilo c.f.s.	Date April	Flow at Celilo c.f.s.
16	139,100	1	255,600
17	137,200	2	247,400
18	118,100	3	232,700
19	129,000	4	238,800
20	151,900	5	239,400
21	159,700	6	245,200
22	137,300	7	242,800
23	192,700	8	225,700
24	205,400	9	221,400
25	215,100	10	218,400
26	227,600	11	219,000
27	252,200	12	231,000
28	286,600	13	247,000
29	269,900	14	265,000
30	338,800	15	280,000
31	250,600	16	290,000
		17	300,000

TABLE 3

RESULTS OF CHEMICAL ANALYSIS IN TILE BOX LOCATIONS

Date 1956	Pearle-Benson ppm	Carbohydrates ppb	COD ppm	CI ppm	BOD ppm	Temp. °C	Velocity (FPS)
Tile Sampler No. 0							
3-29	10		25.8	4.26	1.52	8	
4-2						8	3.6
4-4	0	225	10.7	3.51	1.06	8	
4-5						7	2.1
4-6	0	33.9	9.4	3.83	0.80	7	
4-11						8	1.8
Tile Sampler No. 1							
3-28			15.7	4.58	1.59		
3-29	1.5		20.0	3.72	1.06	8	
4-2						8	0.6
4-4	4.5	193	10.5	3.30	1.08	8	
4-5						7	0.4
4-6	3.0	57.1	6.9	3.40	1.17	7	
4-11						8	0.3
Tile Sampler No. 2							
3-28	0		16.5	5.00	1.68		
3-29	0		20.4	4.05	1.33	8	
4-2						8	0.7
4-4	7.0	214	12.1	3.40	1.63	8	
4-5						7	0.8
4-6	7.0	73.1	10.4	3.83	0.97	7	
4-11						8	0.6
Tile Sampler No. 3							
3-28	0		14.9	4.90	1.51		
3-29	0		19.4	3.94	1.03	8	
4-2						8	1.1
4-4	1.0	161	11.2	3.51	1.21	8	
4-5						7	1.0
4-6	1.5	53.6	8.8	3.40	1.03	7	
4-11						8	0.7

TABLE 3 - continued

Date 1956	Pearle-Benson ppm	Carbohydrates ppb	COD ppm	CI ppm	BOD ppm	Temp. °C	Velocity (FPS)
Tile Sampler No. 4							
3-28	0		16.3	5.00	1.76		
3-29	0		22.5	3.83	1.50	8	
4-2						8	2.1
4-4	22	257	14.5	3.40	1.89	8	
4-5						7	1.4
4-6	15	125	9.6	3.72	1.22	7	
4-11						8	1.6
Tile Sampler No. 5							
3-28	0		18.0	5.65	2.56		
3-29	0		20.3	4.15	1.57	8	
4-2						8	0.5
4-4	19	350	14.1	3.94	1.98	8	
4-5						7	1.1
4-6	11	80.3	12.7	3.94	1.59	7	
4-11						8	1.2
Tile Sampler No. 6							
3-28	0		17.4	5.54	2.28		
3-29	0		20.6	4.05	1.92	8	
3-30	0		17.8	4.58	2.20		
4-2	5.0	90.6	18.9	3.83	2.06	8	0.4
4-4	16	118	13.8	3.83	1.63	8	
4-5	58	179	19.0	4.26	2.61	7	1.1
4-6	11	62.5	11.8	3.83	1.66	7	
4-9	11	96.2	10.9	3.94		8	
4-11	9.0	141	10.9	4.36		8	0.8
Tile Sampler No. 7							
3-28	0		15.7	5.33	1.39		
3-30	10		19.1	4.26	1.66		
4-2	13	125	14.9	3.94	1.39	8	4.0
4-5	22	284	13.5	4.05	1.58	7	4.0
4-9	23	218	9.5	3.72		8	
4-11	19	250	8.6	3.83		8	3.7

TABLE 3 - continued

Date 1956	Pearle Benson ppm	Carbohydrates ppm	COD ppm	CI ppm	BOD ppm	Temp. °C	Velocity (FPS)
Tile Sampler No. 8							
3-30	0		18.1	4.26	1.87		
4-2	6.0	81.3	16.5	3.83	1.89	8	1.2
4-5	46	167	17.1	4.26	2.28	7	1.2
4-9	13	100	10.3	4.26		8	
4-11	7.5	125	9.3	4.26		8	0.9
Tile Sampler No. 9							
3-30	1.0		17.6	4.26	1.79		
4-2	4.5	79.7	16.4	3.72	1.76	8	0.8
4-5	41	171	15.1	4.05	2.02	7	1.3
4-9	11	112	9.0	4.15		8	
4-11	3.5	125	10.1	4.05		8	1.0
Tile Sampler No. 10							
3-30	1.0		16.0	4.47	1.49		
4-2	0	65.6	14.9	3.72	1.60	8	0.2
4-5	33	117	14.5	3.94	1.83	7	0.3
4-9	8	88.5	7.74	4.15		8	
4-11	10	106	6.93	4.26		8	0.4
Tile Sampler No. 11							
3-30	8.0		17.2	4.15	1.37		
4-2	11	73.5	14.0	3.72	0.78	8	3.3
4-5	3.5	142	10.8	4.26	0.72	7	2.2
4-9	4.3	112	7.45	4.36		8	
4-11	9.0	156	9.4	3.72		8	3.3
Tile Sampler No. 12							
3-30	0		18.5	4.26	1.07		
4-2	1.5	102	16.0	3.51	1.23	8	2.3
4-5	1.0	167	10.1	3.94	1.05	7	2.3
4-9	6.5	108	8.22	4.02		8	
4-11	7.5	166	8.18	3.72		8	2.2

TABLE 4

TILE BOX RESULTS

BETWEEN MILE 115 AND 120

APRIL 17, 1956
(After a one-week period of growth)

Tile Box Station	Accumulation in Milligrams per square foot		
	Total Solids	Volatile Solids	Estimated Sphaerotilus & Assoc. Slime Organisms*
0	Not sufficient growth to measure		
1	432.3	33.9	33.9
2	167.0	29.3	27.8
3	685.2	6.2	5.9
4	141.9	19.6	18.6
5	238.7	50.4	47.9
6	1134.5	103.6	98.4
7	168.5	40.3	38.3
8	522.7	65.6	65.6
9	1334.1	97.5	92.6
10	5637.9	26.2	24.9
11	260.2	23.3	22.1

* Corrected by arbitrary substraction of 5 percent where plankton and other drifting organisms occur entrapped in the slime.

TABLE 5

TILE BOX RESULTS

BETWEEN MILE 115 AND 120

APRIL 10, 1956
(After a two-week period of growth)

Tile Box Station	Accumulation in Milligrams per square foot		
	Total Solids	Volatile Solids	Estimated Sphaerotilus & Assoc. Slime Organisms*
0	Not sufficient growth to measure		
1	1844.7	139.7	139.7
3	146.1	30.6	26.5
4	688.2	95.3	85.8
5	1734.9	229.7	206.7
6	4092.2	495.0	495.0
7	307.8	92.2	82.9
8	938.5	250.4	250.4
9	1343.3	189.1	170.19
10	4698.3	288.9	260
11	238.7	41.8	41.8
12	782.8	88.0	79.2

* Corrected by arbitrary substraction of 10 percent by weight where plankton and other drifting organisms occur entrapped in the slime.

TABLE 6

TILE BOX RESULTS

BETWEEN MILE 115 AND 120

APRIL 17, 1956
(After a three-week period of growth)

Tile Box Station	Accumulation in Milligrams per square foot		
	Total Solids	Volatile Solids	Estimated Sphaerotilus & Assoc. Slime Organisms*
0	Not sufficient growth to measure		
1	948.6	113.1	113.1
2	856.7	67.3	60.6
3	197.8	27.7	24.9
4	695.9	69.1	63.2
5	574.2	110.9	99.8
6	1989.5	258.9	233.0
7	312.0	47.3	42.6
8	3484.6	422	422
9	2342.3	305.4	274.9
10	5248.5	316.1	284.5
11	484.7	57.0	51.3

* Corrected by arbitrary subtraction of 10 percent where plankton and other drifting organisms occur entrapped in the slime.

TABLE 7

TILE BOX RESULTS

BETWEEN MILE 103.8 AND 106.5

BETWEEN 62.7 AND 67.9

			Accumulation in Milligrams per square foot		
Station	Date Sampled 1956	Period of Growth in Weeks	Total Solids	Volatile Solids	Estimated Sphaerotilus & Assoc. Slime Organisms*
CG	4-10	1	254.5	31.7	30.1
VRRB	4-10	1	319.6	51.7	49.1
B52	4-10	1	103.3	26.8	25.5
CG	4-18	1	689.2	208.7	198.3
CG	4-18	2	1503.6	241.1	217.0
VRRB	4-18	1	1370.5	156.7	148.9
VRRB	4-18	2	1570.6	300.3	270.3
LLB	4-9	2	47.0	18.9	17.0
LB	4-9	2	2141.0	172.6	153.3
DBL	4-9	2	856.4	123.0	110.7

* Corrected by arbitrary subtraction where plankton and other drifting organisms occur entrapped in the slime: 1-week samples - 5%; 2-week samples - 10%.

TABLE 8 FLOWS IN WILLAMETTE RIVER AT SALEM, OREGON (in 1000 c.f.s.)

	1956								1957			
lows	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
Weekly)													
lax.	26.7	26.7	13.8	7.2	7.8	8.7	46.2	13.4	20.7	23.9	97.8	48.7	19.6
lin.	17.0	21.9	9.9	6.7	6.4	6.5	23.9	10.8	15.1	15.9	40.2	35.0	16.2
lean.	21.2	23.8	12.1	6.92	6.9	7.7	31.2	12.4	18.2	20.3	64.9	43.3	17.8
lax.	36.0	20.3	10.8	6.9	9.6	7.5	23.9	116.0	23.1	20.7	130	41.0	18.7
lin.	25.1	15.9	9.9	6.7	7.2	6.2	18.7	12.0	17.5	16.7	94.6	30.6	16.2
lean.	31.6	17.8	10.4	6.8	8.3	6.8	21.0	57.0	20.9	18.8	111.6	34.7	17.1
lax.	33.0	24.3	9.9	6.7	9.7	9.3	33.5	102.8	22.3	22.7	88.2	28.8	21.4
lin.	25.1	17.1	8.4	6.7	8.7	7.2	15.5	62.0	17.9	18.7	44.4	21.5	17.8
lean.	29.2	20.5	8.7	6.7	9.1	7.9	22.3	80.2	20.4	20.7	63.2	26.3	18.9
lax.	29.3	23.1	8.7	6.9	9.0	38.5	24.7	54.3	23.1	120.0	43.8	19.9	22.3
lin.	20.7	13.7	7.5	6.4	7.0	11.1	14.1	19.5	15.5	18.3	31.1	13.8	14.2
lean.	25.0	17.2	8.1	6.7	8.3	21.1	18.6	33.4	19.3	59.5	36.8	15.9	17.9
Monthly)													
lax.	36.0	26.7	13.8	7.2	9.7	38.5	46.2	116.0	23.1	120.0	130.0	48.7	22.3
lin.	17.0	13.7	7.5	6.4	6.4	6.2	14.1	10.8	15.1	15.9	31.1	13.8	14.2
lean.	26.8	19.8	9.8	6.8	8.2	10.9	23.2	45.8	19.7	29.8	69.1	30.0	17.9

TABLE 9

TILE BOX RESULTS

MARINA MART - ABOVE OREGON CITY

Date	Time Interval Days	Water Temp. °C	Total Solids Mg/sq.ft.	Vol. Sol. Mg/sq.ft.	Vol. Sol. Mg/sq.ft. /da.	Sphaero-tilus % of Vol.	SWL ppm
1957							
5-7	14	14	716	99.6	7.1	None	---
5-14	7	13	322	51.4	7.3	None	---
5-21	7	12	328	87	12.4	Trace	---
5-28	7	14	514	115.6	16.5	Trace	---
6-4	7	18	176	38.4	5.5	Trace	---
5-22	29	13	997	143.2	5.0	0.1	---

TABLE 10

TILE BOX RESULTS

WILLAMETTE RIVER, BELOW OREGON CITY AT SPORTCRAFT

Date	Time Interval Days	Water Temp. °C	Total Solids Mg/sq.ft.	Vol. Sol. Mg/sq.ft.	Vol. Sol. Mg/sq.ft. /da.	Spnaero-tilus % of Vol.	SWL ppm
1956							
6-19	15	15	1155	291.4	19.4	70	55
8-9	30	21	1099	302.2	10.1	80	135
8-17	8	21	353	83.8	10.5	50	107
8-31	14	19	1236	359.6	25.7	60	101
9-28	28	16	1809	514.2	18.3	80	92
10-15	17	14	1025	321.6	18.9	80	190
10-26	11	10	874	326.4	29.7	90	116
11-2	7	9	262	121.2	17.3	95	---
11-14	12	9	1422	549.6	45.8	95	---
11-28	14	5	862	443.9	31.7	90	---
12-12	15	6	388	85	5.7	50	---
8-17	74	21	902	199.6	2.7	--	---
9-18	18	17	4337	918	51	60	---
9-25	39	17	976	300.4	7.7	--	---
11-28	--	5	12101	3528.8	----	--	---
1957							
1-10	29	3	1904	676.4	23.3	80	169
1-24	14	3	3438	1141.4	81.5	40	---
2-6	13	3	1795	478.6	36.8	30	---
2-19	13	5	8094	2198	169	50	---
4-15	5	10	256	133	26.6	--	---
4-23	8	10	740	222.8	27.8	--	---
5-7	14	12	712	133	9.5	--	109
5-14	7	14	503	132.2	18.8	60	---
5-21	7	12	738	191.2	27.3	40	---
5-28	7	16	777	213.8	30.5	80	---
6-4	7	17	371	116	16.6	85	---
1-24	102	3	9832	3248	31.8	30	---
4-23	13	10	4176	663.6	51.0	--	109
5-22	42	13	2357	693.2	16.5	40	---

TABLE 11

TILE BOX RESULTS

EAST PORTLAND MARINA, ABOVE MORRISON BRIDGE

Date	Time Interval Days	Water Temp. °C	Total Solids Mg/sq.ft.	Vol. Sol. Mg/sq.ft.	Vol. Sol. Mg/sq.ft. /da.	Sphaerotilus % of Vol.	SWL ppm
1956							
5-17	8	14	402	67	4.8	20	36
6-4	18	13	1119	192.4	10.7	10	<1.0
6-19	15	15	1430	287.0	19.1	15	45
7-30	20	24	468	176.4	8.8	--	100
8-9	10	20	677	208.6	20.9	10	138
8-17	8	22	333	109.8	13.7	--	99
8-27	10	20	842	204	20.4	Trace	121
9-28	32	16	6032	1084.8	33.9	5	34
10-15	17	14	6548	1078.4	63.4	10	90
10-26	11	10	1761	307.4	27.9	50	162
11-2	6	88	312	83.6	13.9	70	---
11-14	12	9	3844	791.8	66	50	---
11-28	14	5	4416	918.2	65.6	--	63
12-12	14	6	941	170.8	12.8	50	61
12-26	14	5	831	165	11.8	85	120
6-4	26	13	1303	210.4	8.1	--	---
8-17	100	22	1960	706.2	7.1	--	---
9-18	90	18	7736	1220.2	13.5	15	---
11-28	71	5	14258	5388.0	75.8	--	---
1957							
1-10	15	3	1671	436.8	29.1	40	135
1-24	14	3	2597	602.4	43	25	---
2-6	13	3	1799	330.8	25.4	30	---
2-19	13	6	2246	378	29.1	40	---
2-26	7	6	1542	155.8	22.3	40	---
3-13	15	6	2286	242.6	16.2	65	---
3-26	13	8	2220	277.8	21.4	35	---
4-9	14	8	1968	273.2	19.5	40	---
4-23	14	10	1257	178.6	12.8	15	---
5-7	14	14	929	132.6	7.3	--	78
5-14	7	13	816	123	17.6	10	---
5-21	7	13	207	40.4	5.8	10	---
5-28	7	14	297	57.2	8.2	5	---
6-4	7	18	144	48.6	6.9	5	128
1-10	145+	3	2587	676.2	4.6+	60	---
3-26	94	8	12807	1257.8	13.4+	20	---

TABLE 12

TILE BOX RESULTS

COLUMBIA TUG BOAT COMPANY

Date	Time Interval Days	Water Temp. °C	Total Solids Mg/sq.ft.	Vol. Sol. Mg/sq.ft.	Vol. Sol. Mg/sq.ft. /day	Sphaero-tilus % of Vol.	SWL ppm
1956							
7-10	21	14	1341	296.40	14	2	---
7-30	20	23	513	139.20	6.95	10	103
8-10	10	22	385	97.60	9.76	10	94
8-17	8	22	163	57.80	7.48	15	116
8-31	14	21	463	130.00	9.29	Trace	110
9-28	28	17	3052	519.8	18.5	5	98
10-15	17	14	1556	333.20	19.6	10	78
10-26	11	10	862	170.80	15.5	--	110
11-14	19	8	1617	477.40	25.0	10	136
11-27	13	6	671	249.00	19.15	60	77
12-12	15	6	701	161.80	10.7	30	66
12-26	14	6	923	132.40	9.43	65	124
1957							
1-10	15	4	635	157	10.5	20	153
1-24	14	2	450	126.2	9	35	---
2-6	13	2	252	43.2	3.3	30	---
2-19	13	6	781	134.4	10.3	20	---
2-26	7	6	375	52.6	7.5	20	---
3-13	15	6	659	105	7.0	90	---
3-26	13	8	431	64.4	5.0	65	9
4-9	14	9	665	142.2	10.1	50	---
4-23	14	10	1048	365	26.1	5	---
5-7	14	11	3458	547.8	39.1	--	76
5-14	7	14	959	203.2	29	Trace	---
5-21	7	14	246	41.8	6.0	Trace	---
5-28	7	14	136	42.8	6.1	Trace	---
6-4	6	18	163	66	11	Trace	134
1956							
9-18	117	19	903	217	1.85	--	---
11-27	88	6	3147	691.2	7.89	--	---
1957							
2-6	--	2	3655	879.2	----	--	---
3-26	48	8	3397	466.0	9.7	--	---

TABLE 13

TILE BOX RESULTS

GAYS MOORAGE - MULTNOMAH CHANNEL

Date	Time Interval Days	Water Temp. °C	Total Solids Mg/sq.ft.	Vol. Sol. Mg/sq.ft.	Vol. Sol. Mg/sq.ft. /da.	Sphaerotilus % of Vol.	SWL ppm
1956							
5-17	8	12	83	9.6	1.2	None	17
6-4	18	14	457	71.5	4	None	<1.0
7-30	20	22	370	56	2.8	10	6
8-9	10	20	435	68.80	6.9	---	13
8-31	22	20	498	86.40	3.9	Trace	---
9-28	28	17	1725	237	8.5	2	---
10-15	17	14	1866	287	16.9	5	---
10-26	11	11	640	149.40	13.6	---	---
11-14	19	9	1926	296	15.6	20	---
11-27	13	6	516	124.2	9.6	30	---
12-12	15	5	1886	452.2	28.3	50	---
12-26	14	6	560	93.2	6.7	60	---
6-4	26	14	939	156	6	---	---
9-18	124	18	1932	324.6	2.6	---	---
11-27	70	6	8252	3134	44.8	---	---
1957							
1-10	15	3	1420	273.4	18.2	30	---
1-24	14	2	1508	318.2	22.7	25	---
2-6	13	2	780	140.4	10.8	10	---
2-19	13	6	1579	223.2	17.2	15	
2-26	7	6	383	53.4	7.6	15	---
3-13	15	7	482	77.6	5.2	85	---
3-26	13	7	5064	221.2	17.0	60	---
4-9	14	8	469	80.6	5.8	10	---
4-23	14	10	431	63.8	4.6	Trace	---
5-7	14	13	196	33.6	2.4	---	---
5-14	7	12	18	5	0.7	Trace	---
5-28	14	12	116	23.8	1.8	2	---
6-4	7	15	82	14.4	2.1	2	---
2-6	71+	--	13280	2037.2	28.6+	---	---
4-9	62+	--	11400	1368	22.0+	---	---